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STOCK ASSESSMENT OF CEPHALOPOD RESOURCES FISHED BY JAPAN

by

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PREPARATION OF THIS PAPER

This review was prepared by Dr. T. Okutani, in association with other Japanese scientists, as part of FAO's general review of world fishery resources, and in particular of the less familiar resources which might support increased exploitation. Support for this work was received from the United Nations Environment Programme as one element of the cooperative project of UNEP and FAO on the monitoring of environmental effects on marine world fishery resources.

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Abstract

The distribution and abundance of the resources of cephalopods fished by Japan are reviewed. Japanese fishermen take over half the world catch of these species. The main Japanese fisheries are around the coast of Japan, but significant catches are taken off New Zealand and off northwest Africa and stocks in several other areas are being fished on a commercial or experimental basis. By far the most important species (rather more than half the total) is _Todarodes pacificus_, caught by jigging. The rest of the Japanese catch consists of other squids (15-20 percent of the total), octopods (10-15 percent) and cuttlefish (around 5 percent). Most of the stocks around Japan are fully exploited, and the important winter stock of _T. pacificus_ appears to have been depleted by heavy fishing. The stocks on the northwest African continental shelf (mostly caught by trawling) also appear to be heavily fished. On the other hand the fisheries to the northeast of Japan on oceanic squids seem to be affecting only the fringe of very substantial stocks. It is believed that world-wide these species represent a very large and important resource.

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1. PREFACE

1.1

It is estimated that the potential world production of marine fisheries from the traditional types of fish is no more than 100-120 million tons. At the current rate of increase, catches will approach this limit within the coming 10 years. To cope with the population explosion, the exploitation of other less familiar marine resources is indispensable for securing additional protein supplies. The exploitations of Antarctic krill (euphausid) and hitherto untouched stocks of squids by Japan in recent years provide one approach to this problem. Better knowledge of these unfamiliar resources is therefore needed.

Consideration of cephalopods has been included in earlier general reviews of fish resources. A review made by the Fishery Agency, Japanese Government (1968) on the current state of exploited marine resources and of latent or promising stocks of marine animals included an examination of cephalopod resources. Some estimates of cephalopod stock size were also done by Gulland (1970) whose comprehensive study became an important benchmark for the succeeding works. The interest shown by the Japanese Government and FAO stems from the belief that cephalopod resources may be a promising protein source.

With such a background, the present study was suggested by FAO, and was completed with the positive support and cooperation of Dr. Mototsugu Hamabe, the Director of the Japan Sea Regional Fisheries Research Laboratory, Niigata, who organized the working team for preparation of background papers and contributed important parts of this report. The following colleagues contributed background papers on which the present review is based:

Dr. Hisao Araya, Hokkaido Regional Fisheries Research Laboratory, Yoichi (on the Pacific stock of *Todarodes pacificus*),

Mr. Shogo Kawahara, Japan Sea Regional Fisheries Research Laboratory, Niigata (on the Japan Sea stock of *T. pacificus*),

Dr. Takehiko Kawakami, Tokai Regional Fisheries Research Laboratory, Tokyo (on the non-Japanese squids taken by jigging),

Dr. Tetsuya Sato, Far Seas Fisheries Research Laboratory, Shimizu (on the cuttlefish stock in the Arabian Sea), and

Mr. Mamoru Murata, Hokkaido Regional Fisheries Research Laboratory, Yoichi (on some oceanic squids).

FAO arranged for the editor to visit Rome to complete the compilation and editing of this report.

The thanks of the editor are due to Dr. M. Hamabe and other contributors of background papers mentioned in the early part of this section. Mr. Shigeyuki Kasahara, Far Seas Fisheries Research Laboratory, Shimizu, kindly permitted me to cite his unpublished manuscript before it is submitted to ICNAF.

Finally, the editor thanks Drs. John A. Gulland, Shiro Chikuni and William G. Clark, Aquatic Resources Survey and Evaluation Service, FAO, for their valuable comments and discussions for the improvement of the report.

Cephalopods

Cephalopods form a distinct group of the Phylum Mollusca (soft and non-segmented bodied invertebrates), including octopus, squid and cuttlefish. The octopus is an eight-armed cephalopod comprising some 150-200 species in the world oceans. The best known species is the common octopus which lives on benthic life in tidal and subtidal beds. Among octopuses

there are nektonic (swimming) and planktonic (floating) forms which have a bizarre shape of body. The squid is a ten-armed cephalopod usually with a slender body and feeding on nektonic life mostly in an oceanic environment. The representative species are strong swimmers with muscular bodies such as flying or short-finned squid (Ommastrephidae) and long-finned squid (Loliginidae). Cuttlefish is also a ten-armed cephalopod and may be called squid in a broad sense. However, most cuttlefish have short bodies and an internal shell (cuttlebone), except bob-tailed cuttlefish (Sepiolidae, etc.) and pigmy cuttlefish (Idiosepiidae). Cuttlefish are usually neritic species feeding on bottom-associated life although they are capable of swimming like squid. Altogether there are at present some 450-500 species of squid and cuttlefish belonging to 30 families.

The biology of cephalopods has not been studied well. The eggs of benthic octopus, cuttlefish and some squid (Loliginidae, etc.) are encased in a gelatinous egg-case and laid on the bottom but those of the oceanic species are spawned separately (Enoploteuthidae) or in a form of floating egg mass (Thysanoteuthidae). The spawning behaviour and eggs of the family Ommastrephidae in the natural environment is not known. Hatched larvae are spread out by action of the water movement. For instance, the distribution pattern of larvae of the Japanese oceanic species, Todarodes pacificus, corresponds well to the meandering of the major current, Kuroshio. Juveniles grow as they prey upon small crustaceans, fish and molluscs. Benthic octopods adopt a nest and territory as they grow while nektonic squid commence schooling and migration.

Take as an example Todarodes pacificus which is the most common and abundant squid around Japan. T. pacificus lives in water of low temperature at the stage of feeding and migration toward the north, and in water of higher temperature at the time of reproduction during the southward migration. Males mature earlier than females and copulate with the immature females. The female is impregnated with immature sperm bulbs around the outer lip. The sperm bulbs are accumulated as time passes during the southward migration. The maturity process of the gonads of both sexes is an important clue in tracing a particular shoal from the beginning to the end.

1.3 Cephalopod Fisheries

The cephalopod fishery is most diverse and prosperous in Japan. The majority of octopus is taken by octopus-pot and a minor portion of the octopus catch is by bottom trawling. Cuttlefish are caught by bottom trawling and fished locally by set-nets, angling and trap. The neritic squid, especially members of the family Loliginidae, are taken by a variety of gears, for example, bottom trawl, set-net, blanket-net, seines and jigging. The loliginids in the Atlantic area are taken only by trawling, while the Californian species is taken by dip-net and pumping.

The largest squid fishery in Japan is for an ommastrephid, Todarodes pacificus. This species is taken by angling, using squid jigs which consist of a plastic stem with one to three stages of barbs on the bottom. This was traditionally made of horn or lead, but is now plastic. This method of fishing is very well matched to the behaviour of squid in that it is easily attracted to the fast-moving bait. Previously jigging was operated by handline but is now operated by motor-driven drums installed on the ship's side. This method has now become popular in various parts of the world for catching ommastrephids.

Fishery biological aspects of cephalopods (those taken in the Japanese fishery) and fishing gears and method are thoroughly reviewed by the Fisheries Agency (1975) and FAO (1976).

The present world pattern of exploitation by cephalopod groups may be summarised as follows:

(i) Octopus

Total catches are some 120 000 tons (mainly Octopus vulgaris). More than 90 percent of the catches are by Japan and Spain. Japanese fishing has not been restricted to the waters

around Japan, but 20 000-30 000 tons are taken by trawlers in African waters and 20 000-100 000 tons in the North Pacific. There may be no room for developing the octopus fishery in the Japanese waters, but there may be more underutilised stocks (probably several hundreds of thousands of tons each) in the Atlantic and the waters around North America and Australia.

(ii) Cuttlefish

About 10 000 tons are taken around Japan and 30 000 tons along the northwest African coast. There may be large stocks in the Southwest Pacific.

(iii) Loliginid squids

The stocks are believed not to be large, though there are significant local fisheries in parts of southeast Asia. Other stocks that could support moderate scale fisheries occur in the inshore waters in the North Atlantic and off North America.

About three quarters of the world squid catch has been occupied by the Ommastrephidae. The most important single species is *Todarodes pacificus* which makes up as much as 80 percent of the total cephalopod catch of Japan. A few other species among this family support local fisheries, including *Illex illecebrosus* off Newfoundland, *Todarodes sagittatus* in the North Atlantic and *Nototodarus sloani* in New Zealand. The fishing effort on *T. pacificus* seems to have attained or passed the optimum level, so that there may be no room for further exploitation of this species. However, there may be good chances of developing fishing grounds for other ommastrephid species, in the North and South Atlantic off both the European-African, and American coasts, in the East Pacific and in the waters around Australia.

The specialised jigging fishery for catching squid has been restricted to Japanese, Korean and Chinese fishermen. In regions where this method has not been used, the information used to estimate the nature of the resources has been mostly incidental catches by trawlers. In the history of development of cephalopod fisheries operated in the coastal waters of Japan, the trawl fishery usually pioneered the exploration of virgin stocks in shelf zones, and later more effective and selective methods (angling or jigging) followed for exploitation on a commercial scale. The cephalopod fishery in Japan has expanded in correspondence with the increase of national demand. The growth of fisheries has been supported by a well-balanced backup in three fields: biology, fishing technology and processing science. These have provided an indispensable base for the development of the squid fishery. A good example is the recent development of jigging fishery in New Zealand waters and other areas with the help of application of biological knowledge of Japanese congener, *Todarodes pacificus*.

A number of commercial trawl fisheries directed entirely or mainly at cephalopods have been successfully developed. These include those in the ICNAF (Northwest Atlantic) and CECAF (West African) regions carried out by trawlers from Japan and Mediterranean countries (principally Spain and Italy).

Some of these jigging and trawl fisheries appear to be approaching or have even the limit set by the potential of the stocks they are exploiting. Therefore the state of these exploited stocks is of as great practical interest as is the potential of stocks still unexploited; both aspects are considered in this report. The approach has been to examine first the stocks in the waters around Japan (Section 2), then the stocks in more distant waters exploited by Japanese fishermen (Section 3) and then attempt to generalise from this to the world resources as a whole, with suggestions for action and further study (Section 4).

2. DOMESTIC RESOURCES

Japan has the most extensive and intensive utilisation of cephalopods in the world. In 1968 the cephalopod catch by Japan was 877 000 tons (774 000 tons of squid and cuttlefish and

103 000 tons of octopus), which is almost one tenth of the Japanese catch of all marine animals and was some 72 percent of the total world cephalopod catch of 1 211 000 tons (Table 2.1).

The commercial species, including those supporting local fisheries, ranges over many families of cephalopod inhabiting both inshore and oceanic waters around the Japanese islands. There are large varieties of catching methods for cephalopods corresponding to differences in the habitat and ecology of the species at which the fisheries are directed. In addition all cephalopods taken as incidental catches in fisheries aiming at other fish are landed.

Table 2.2 lists 31 species that are utilized to a greater or lesser extent out of some 40 species of octopods and 90 species of squid and cuttlefish that occur in Japanese waters (Sasaki, 1929; Okutani, 1967, 1973). The table also gives information on the location and method of fishing. Detailed statistics and condition of stocks of selected species appear in Section 2.5.

2.2 Population Structure of *Todarodes pacificus*

There has been a long history of biological studies on *Todarodes pacificus* Steenstrup, mostly concerned with biological investigations of direct fishery interest. These have enabled three populations or subpopulations with different breeding seasons to be distinguished on the basis of size composition, maturity process and migratory pattern. They are called "winter", "summer" and "autumn" populations by the fishery biologists particularly concerned with this species. Each of these populations can be further divided into the Pacific and Japan Sea fractions. The winter population is the main support of the fishery on the Pacific coast of Japan. The autumn population supports the major part of offshore squid fishery in the Japan Sea since exploitation began in 1970.

2.2.1 Winter population

This population has the most extensive habitat ranging from the East China Sea up north to the coasts of Sakhalin and mid- to southern Kuril Islands. The major fishing ground is located off the Pacific coasts of northeastern Honshu and Hokkaido, but squids belonging to this population have occasionally been caught in the Yellow Sea and off the Sakhalin coast.

The larvae of this population are distributed in the shelf area extending from the west coast of Kyushu and East China Sea up north to the Pacific coast of eastern Honshu and the Japan Sea coast of middle Honshu. Larvae are particularly abundant in the waters along the west and south coasts of Kyushu and south coast of the Korean Peninsula during January to February. The general distribution pattern along the Pacific coast corresponds well to the meandering of the Kuroshio Current by which larvae are carried to the northeast along the Japanese islands while they grow. The grown larvae or juveniles appear on the west coast of Kyushu during January to April, and in the western part of the Japan Sea as well as the Shikoku-western Honshu area on the Pacific coast during March to May. They move further north along the Pacific coast of northeastern Honshu and Hokkaido during April to June. Juveniles are frequently caught by fixed nets set along the beach and also found concentrated around fronts bordering warm and cold water masses in both the Pacific and the Japan Sea.

In August, the major part of north-going shoals of squids, which have grown to 20 cm in mantle length, reach the northern-most limit of their distribution range which is 52°N in the Japan Sea and occasionally 49°N in the Pacific. The male mature earlier than the female does and copulates. In September the shoals commence their southward migration as the water temp rature begins to drop. But the movement at this season is gradual so that fishing activity remains at a similar intensity to that in August. The southward migration is accelerated in October and November when recruitment from the offshore area makes fishing activity very prosperous in northeastern Honshu and Hokkaido. Thus, the fishing for the summer season is aimed at shoals staying there until September, but that for the autumn is at squid recruiting from the offshore area in the open Pacific. In the Japan Sea, the winter population commences its southward migration by October.

Cephalopod catches in Japan and the world (1960-1974)

(metric tons)

Year	JAPAN						WORLD
	Total	Octopods	Subtotal Decapods	*Todarodes pacificus*	Cuttlefish	Other Decapods	All Cephalopods
1960	599 447	57 601	541 846	480 661	19 116	42 069	725 000
1961	513 757	56 857	456 900	383 993	19 845	53 062	695 000
1962	679 069	65 561	612 508	536 470	23 735	52 303	841 000
1963	731 024	63 902	667 122	590 647	14 937	61 538	959 000
1964	396 349	66 975	329 374	238 290	23 216	67 868	624 000
1965	577 424	78 057	499 367	396 902	20 394	82 071	847 000
1966	550 578	65 551	485 027	382 899	15 421	86 707	829 000
1967	694 978	98 130	596 848	477 012	15 736	104 100	945 000
1968	876 495	102 718	773 777	668 364	15 348	90 065	1 211 000
1969	682 216	92 418	589 798	478 160	16 465	95 173	981 000
1970	615 044	96 127	518 917	412 240	14 740	91 937	948 000
1971	568 025	85 507	482 518	364 349	15 413	102 756	906 000
1972	666 307	66 857	599 450	464 365	15 090	119 995	1 109 000
1973	550 021	63 764	486 257	347 566	12 225	126 496	1 055 000
1974	546 664	76 731	469 933	335 005	17 169	117 759	1 058 000

Cephalopods commercially taken in
(including those taken incidentally in fisheries for other

Family	Species	Locality	Gears[1/]
Sepiidae	*Sepia lycidas* Gray	S.W. Japan, E. China Sea	TR, FN, AJ
	S. esculenta Hoyle	Whole Japan excluding N. Hokkaido	TR, FN, AJ
	S. latimanus Quoy and Gaimard	Amami-Okinawa	SP, AJ
		W. Japan, Inland Sea	TR
	Wülker	W. Japan, Inland Sea	TR
	S. andreana Steenstrup	N.E. Japan	TR, FN
	Sepiella japonica Sasaki	W. Japan, E. China Sea	TR
Sepiolidae	*Rossia pacifica* Berry	N.E. Japan	TR
	Verrill	Inland Sea	TR
Loliginidae	*Sepioteuthis lessoniana* Lesson	Whole Japan, excluding N. Hokkaido	FN, AJ
	Doryteuthis bleekeri (Keferstein)	Whole Japan, excluding N. Hokkaido	TR, FN, AJ
	Loligo edulis Hoyle	W. Japan	TR, FN, AJ
	Wakiya and Ishikawa	Japan Sea	TR, FN
	Hoyle	Whole Japan, excluding N. Hokkaido	FN, BS
	L. beka Sasaki	Inland Sea, W. Kyushu	FN, TR, BS
	L. kobiensis Hoyle	Inland Sea, Kyushu	FN, TR, BS
	L. uyii Wakiya and Ishikawa	Inland Sea, Kyushu	TR, FN, BS
Enoploteuthidae	*Watasenia scintillans* (Berry)	Japan Sea (Toyama Bay)	FN
Onychoteuthidae	*Onychoteuthis borealijaponica* Okada	E. Japan	AJ
Gonatidae	*Berryteuthis magister* (Berry)	N. Japan	TR
	Gonatopsis borealis Sasaki	N. Japan	AJ
		Okinawa	AJ
	Ommastrephes bartrami (LeSueur)	N.E. Japan (Pacific)	AJ
	Todarodes pacificus Steenstrup	Whole Japan	AJ, FN, TR
Thysanoteuthidae	*Thysanoteuthis rhombus* Troschel	Japan Sea	AJ
Octopodidae	*Octopus vulgaris* (Lamarck)	Whole Japan, excluding	OP, AJ
	O. ocellatus Gray	W. Japan	OP
	O. minor Sasaki	Inland Sea, W. Japan	TR, OP
	O. conispadiceus Sasaki	Hokkaido	TR, OP
	O. araneoides Taki	Hokkaido	TR, OP
	Paroctopus dofleini (Wülker)	N.E. Japan	TR, OP

1/ AJ: angling and jigging, BS: boat seines, FN: fixed (stationed) net, OP: octopus pot (trap), SP: spearing, TR: trawling (of various scales)

2.2.2 Summer population

This population occurs in both the Japan Sea and the Pacific coast, but is restricted in geographical range and, therefore, it is the most localised population. In the Japan Sea, larvae of this population are found around Sado Island and Oki Islands during August to October, and also the west coast of Kyushu in May-July. Juveniles seem to move to the northern Japan Sea where they grow until they migrate down south to the southwestern Japan Sea where they pass the winter. These squids occur sporadically everywhere in the Japan Sea during May to August.

In the Pacific there is a small population that matures and spawns in the area around the Boso and Izu Peninsulas in April to August. The mature size is much smaller than the other (23-27 cm mantle length) and the population size is also very small.

2.2.3 Autumn population

In the Pacific there is a small population that matures in September to October on the Jōban coast. A small fraction stays around the middle Honshu even after a large winter population has migrated up northward. These are regarded as the autumn population of the Pacific side.

On the contrary, the autumn population in the Japan Sea is huge both in stock size and in the size of the animal. The major habitat extends from the East China Sea and the west coast of Kyushu north to the coast of the Maritime Province, U.S.S.R., and to 45°-46°N at the western entrance of the Soya Straits and includes the offshore area of the Japan Sea. The spawning area seems to be located around the middle to the southwestern part of the Japan Sea and to be extended to the northern part of the East China Sea. The larval population occurs south of 39°N along the coast of the middle and western Honshu during September to November and also in the shelf area of the northern East China Sea during October to December. The behaviour of juveniles of this population is not well known, except sporadic catches are taken along the coast from western Kyushu to middle Honshu. In May, squid of 15-18 cm mantle length are caught in branches of the Tsushima Warm Current, such as around Takeshima Island, and in the Oki-San'in and Noto-Sado Island areas. These seem to be making a northward migration. In June they are spread over the offshore area of the Japan Sea south of 42°N and in July, even north of 42°N. The major habitat is limited at around 45°-46°N. In September some 90 percent of males and 70-80 percent of females mature and start the southward migration. The major body of the population reaches to the east coast of the Korean and Tsushima region as well as the coast of middle and western Honshu during mid-September to October. They mostly disappear from the Japan Sea in the mid- to late November (Figure 2.1). The statistics broken down to country and major populations are shown in Table 2.3.

2.3.1 Catch, fishing effort and CPUE

As was reviewed in the foregoing section, the major part of *Todarodes pacificus* fishery in the Pacific has been supported by the winter population. From the waters around northern Honshu and Hokkaido, some 90 percent of the catches from the winter population have been landed. Particularly, the fishing grounds located off the Pacific coasts of northeastern Honshu and Hokkaido yielded great catches which until 1968 accounted for more than 80 percent of total Japanese landings of this species. The catch, however, has declined since 1969 to as low as 10 percent of the maximum in very recent years. The maximum catch from this population in history was 490×10^3 tons in 1968 and minimum 38×10^3 tons in 1973. There were several falls and rises since 1950: the fall in the 1950s was to 200×10^3 tons, in the 1960s to 100×10^3 and in the 1970s the catches became even lower than that level. The general decreasing tendency is clearly shown in Figure 2.2.

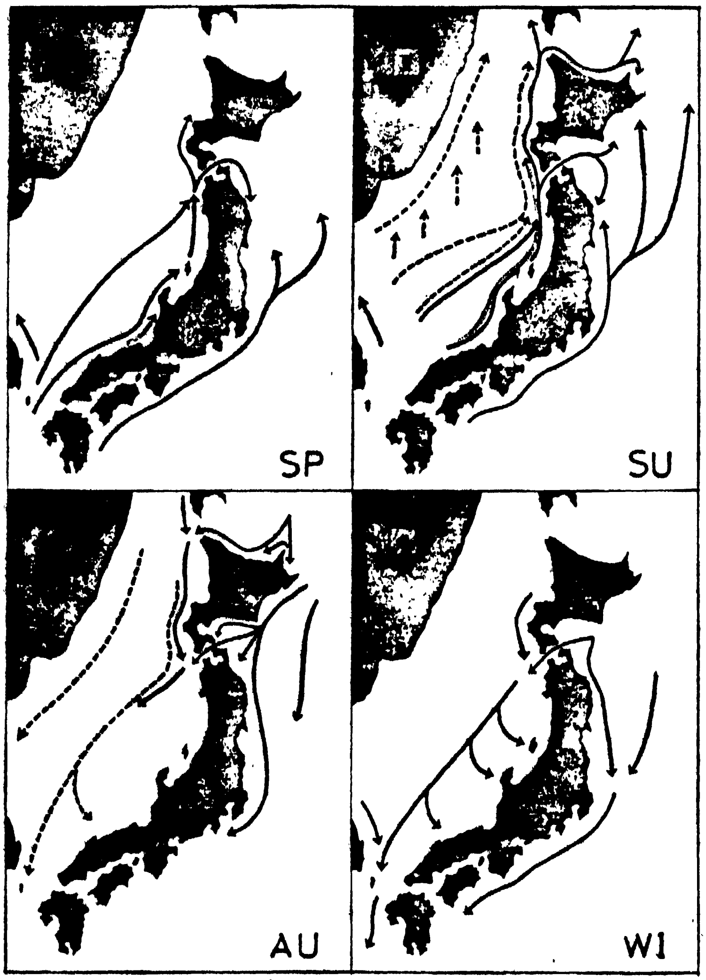


Figure 2.1 Assumed migratory routes of Todarodes pacificus by season (Araya, 1967) Solid lines: winter population; dotted lines: summer population; broken lines: autumn population

Table 2.3

Todarodes pacificus catches in the Northwest Pacific region by country and by seasonal population (x 10^3 tons)

Year	JAPAN				R.O.K.[a]	D.P.R.K.	U.S.S.R.[c]
	Total	Japan Sea[a]		Pacific[b]			
		Winter	Autumn	Winter	Autumn		
1965	396.9	104.2	7.9	(329)	68.4	No data	5.9
1966	382.9	106.3	10.1	(317)	75.5		3.2
1967	477.0	106.4	17.7	(388)	38.9		7.3
1968	668.4	143.2	29.4	(544)	84.7		2.7
1969	478.2	82.1	49.5	(364)	59.9		11.4
1970	412.2	140.7	81.0	(273)	72.1		0.6
1971	364.3	85.3	117.0	239	37.6		11.4
1972	464.4	109.9	205.9	310	52.7		7.9
1973	348.6	107.3	197.5	195	44.2		6.0
1974	335.0	95.9	179.8	223	31.4		8.7

a/ From S. Kasahara (personal communication, 1977)

b/ From H. Araya (personal communication, 1977). Particularly after 1970, this column includes a substantial proportion of catches taken in the Japan Sea. Hence the total on the left, which is correct, is not equal to the sum of the components

c/ From FAO Yearbook of Fishery Statistics 1970, 1970. Species not identified

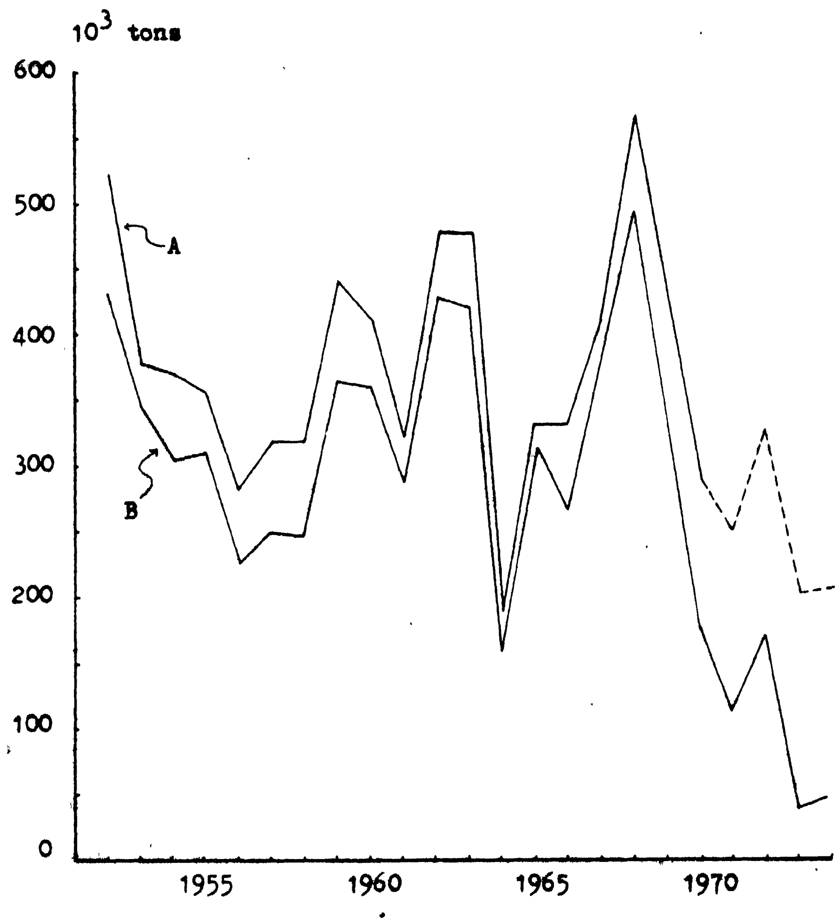


Figure 2.2 Catch of the winter population of Todarodes pacificus

A: From all fishing grounds of northern Japan (both the Pacific and Japan Sea)

B: From the Pacific (south of Hokkaido and east off northeast Honshu)

Figure 2.3 shows the fluctuation in fishing effort in terms of the number of fishing days by each tonnage class of fishing boat. From this, it is clear that the boats smaller than 3 tons and in the 20-30 tonnage class increased during the 1960s but declined in recent years, while the number of 10-20 ton class boats has been rather consistent through the period. The number of boats in all other classes has increased up to the present. The rapid increases of larger boats, namely 50-100 tons and over 100 tons, are remarkable. This fact suggests that fishing effort, as a whole, has tended to increase.

Figure 2.4 shows the average catch per day for each tonnage class of fishing boat. It may be noted that with the logarithmic scale used the parallel lines for each tonnage class represent consistent measures of the change in relative abundance. The catch per boat was high until 1963 when it began to decline. Even in 1968, the year of highest catch, CPUE was lower than in previous years. Since 1969, the rate of decrease has accelerated. In 1972 there was a temporary rise in the CPUE of the larger boats which may be because these boats have also been operating in the central part of the Japan Sea. It is clear that the stock level of the winter population is at a low level.

2.3.2 Estimation of potential yield with catch and effort data

By standardising the fishing effort by all vessel size classes to equivalent effort by vessels in the 10-20 ton class, Araya (1973) estimated total fishing effort in each year from 1954 to 1970 for the squid fisheries of northern Japan, which during those years was mostly supported by the winter population of T. pacificus (after 1970 the fishery expanded onto other populations in the central part of the Japan Sea). The series of total catch and effort data (Table 2.4) therefore shows the effect on the winter population of the increase in fishing effort that took place during the period.

Figure 2.5 shows the empirical curvilinear relationship between catch per effort and total effort. Catch rates clearly decreased greatly as effort increased, with a resulting decline in total catch. It can be calculated from the curvilinear relationship in the figure that a maximum equilibrium catch of 389 000 tons (on the average) could be taken with an effort of 385 000 standard boat days. A linear relationship fits the data almost as well, and implies a maximum catch of 431 000 tons with an effort of 372 000 standard boat days.

Since fishing effort had increased to nearly 600 000 standard boat days by 1970 and has not decreased since, it appears that the recent sharp decline in total catch resulted from overfishing. In this case, reducing fishing effort to about the 1966 level would restore the average annual catch to the maximum level of around 400 000 tons, although the scatter of points about the fitted line in Figure 2.5 shows that the actual catch taken at this level of effort would fluctuate considerably from year to year. Reducing effort would of course increase catch rates as well as the total catch.

2.3.3 Results of marking experiments

Tagged squid were released on the fishing grounds south of Hokkaido in 1952, 1954 and each of the years 1956-1959. Rates of return varied from 8 to 23 percent (Table 2.5). Soeda et al. (1953) found in tests at a drying farm that 68 percent of tagged squid processed at the farm were reported. Adjusting the actual numbers of tags returned for this rate of reporting implies that 12 to 35 percent of tagged squid must have been recaptured during the experiments. This estimate of the rate of exploitation of the population by the fishery in this area may be somewhat high or somewhat low for various reasons, but it does indicate that the rate of exploitation was high even twenty years ago. At that time annual catches were 300 000-400 000 tons, close to the maximum calculated in the last section.

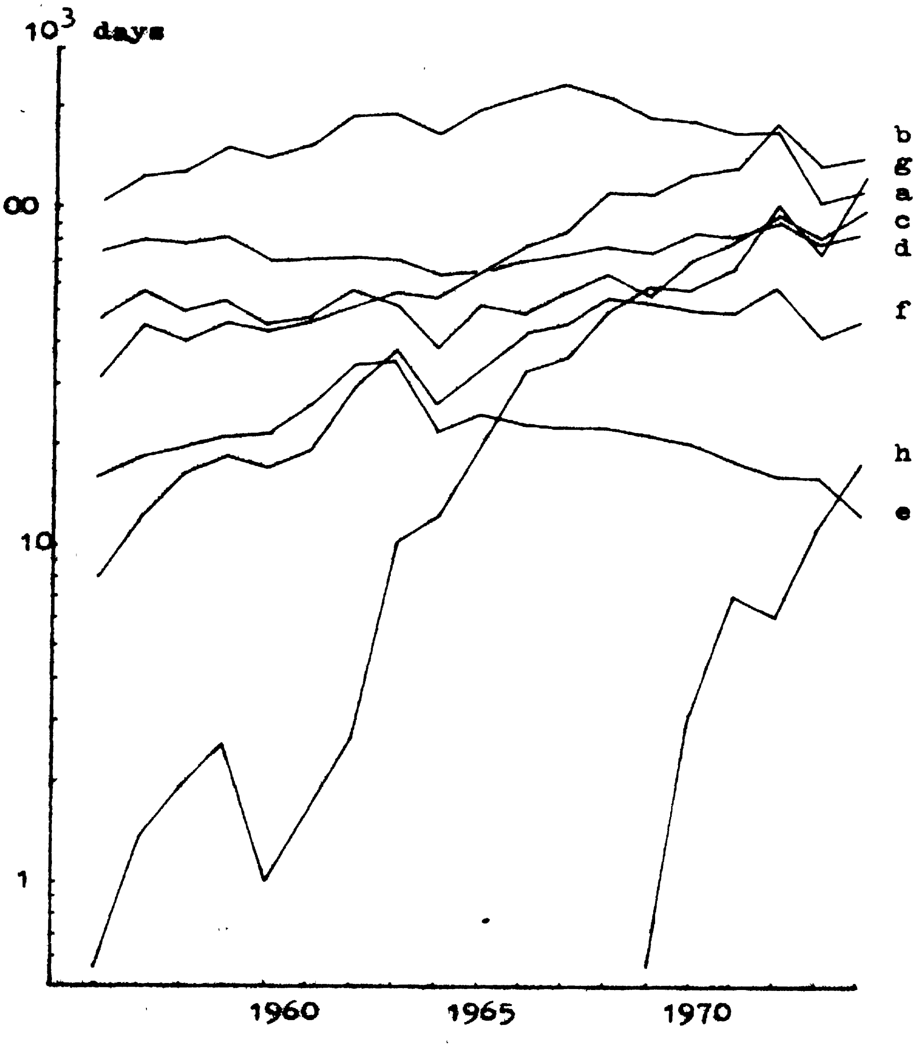


Figure 2.3 Fishing days by tonnage class of boats
a: less than 3 tons, b: 3-5 tons, c:5-10 tons,
d: 10-20 tons, e: 20-30 tons, f: 30-50 tons,
g: 50-100 tons, h: over 100 tons

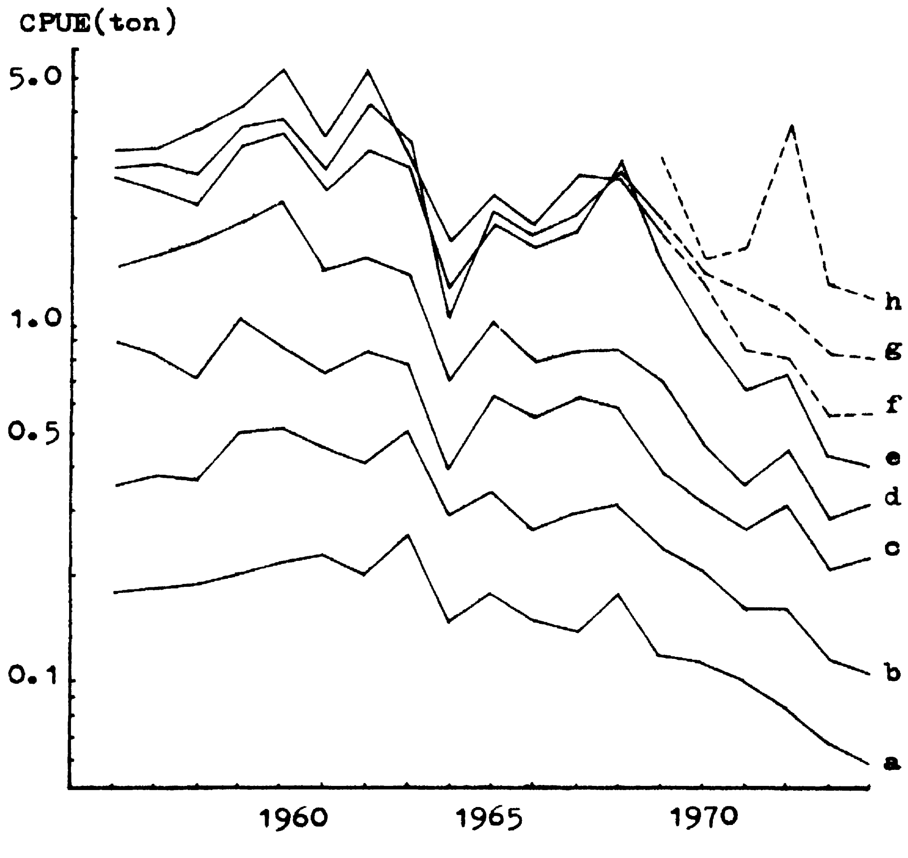


Figure 2.4 Mean catch per day by tonnage class of boat
a: less than 3 tons, b: 3–5 tons, c: 5–10 tons,
d: 10–20 tons, e: 20–30 tons, f: 30–50 tons,
g: 50–100 tons, h: over 100 tons

Catch (C) and numbers of fishing days (N) in the fishery for T. pacificus in northern Japan (1954-1970)

Year	C (10^3 tons)	N (10^3 days)
1954	350	162
1955	341	160
1956	247	171
1957	299	188
1958	305	177
1959	421	214
1960	398	178
1961	318	220
1962	471	299
1963	477	340
1964	176	255
1965	329	320
1966	317	398
1967	388	459
1968	544	567
1969	364	517
1970	273	575

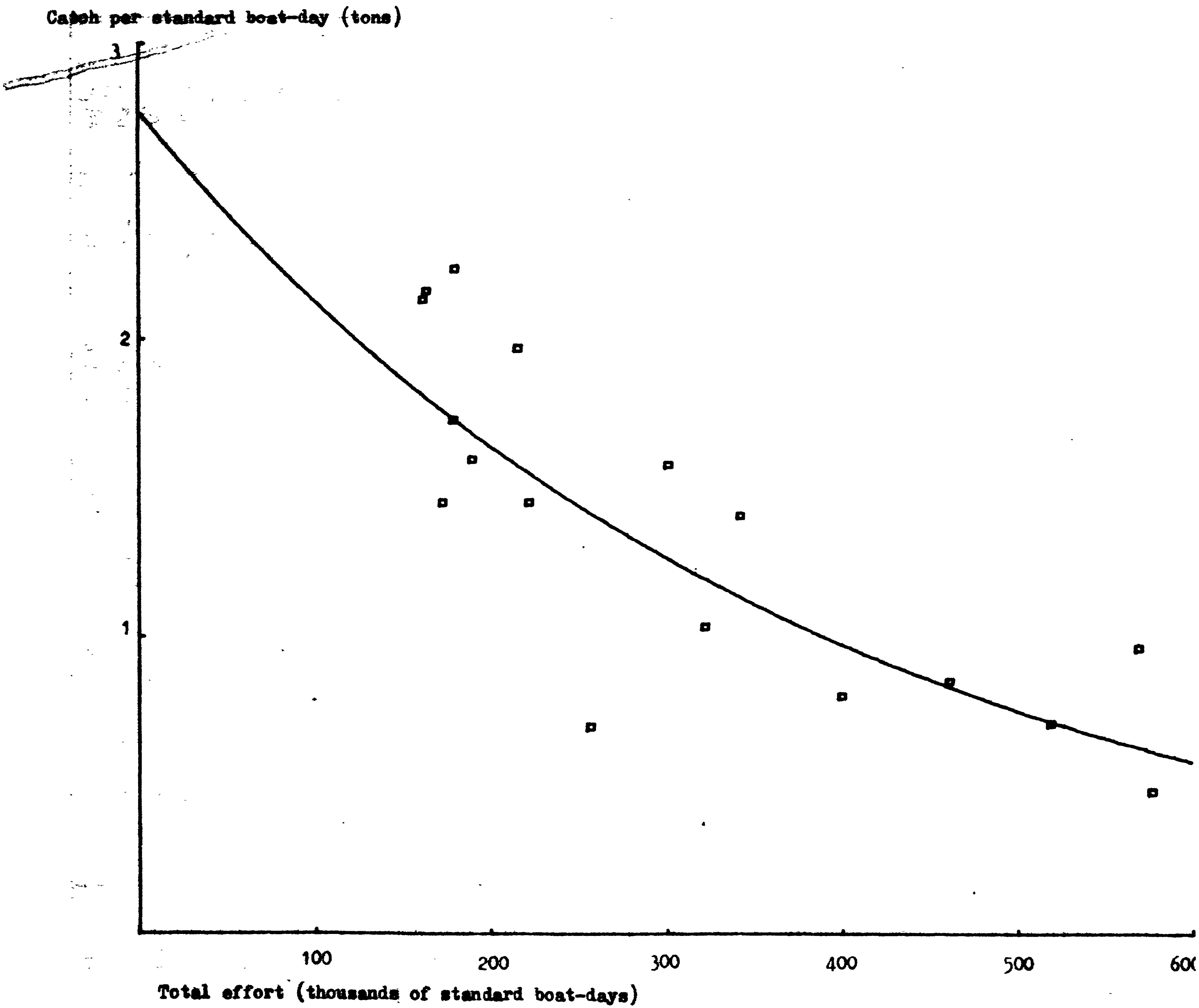


Figure 2.5 Relationships between catch per effort and total effort, northern Japan, 1954-1970

Results of tagging experiments in the fishing grounds south of Hokkaido (1952, 1954 and 1956-1959)

Year	Number of squids tagged	Days passed							Recovery rate
		~30	~60	~90	~120	~150	unknown	Total	
1952	1 200	195	14	5	0	2	5	221	0.18
1954	608	109	27	2	0	0	0	138	0.23
1956	2 699	160	62	5	0	0	0	227	0.08
1957	2 074	244	61	10	1	1	0	317	0.15
1958	1 774	176	20	2	0	0	0	198	0.11
1959	1 095	141	31	5	0	0	0	177	0.16

Table 2.6

Estimated catch of *T. pacificus* in the Japan Sea by population and proportions from different populations

Year	Total	Catch (ton)			Ratio (%)	
		Winter	Autumn		Winter	Autumn
			Japan	Korea		
Mean for 1955-1959	108 423	73 520	2 965	31 938	67.8	32.2
Mean for 1960-1964	175 439	95 149	3 190	77 100	54.2	45.8
1965	180 546	104 204	7 944	68 398	57.7	42.3
1966	191 894	106 333	10 088	75 473	55.4	44.6
1967	163 063	106 357	17 743	38 945	65.2	34.8
1968	257 261	143 160	29 437	84 664	55.6	44.4
1969	191 759	82 074	49 787	59 898	42.8	57.2
1970	293 867	140 679	81 046	72 142	47.9	52.1
1971	239 973	85 328	117 020	37 625	35.6	64.4
1972	368 507	109 883	205 924	52 700	29.8	70.2
1973	348 949	107 274	197 475	44 200	30.7	69.3
1974	307 044	95 922	179 768	31 354	31.2	68.8

2.4

2.4.1 Catch

Todarodes pacificus catch in the Japan Sea is taken from three populations having different breeding seasons. The fishing conditions are strongly influenced by the size of accessible stock that comes within the reach of fishing activity. The recent increase of catch in the Japan Sea is due to the development of an offshore fishing ground covering the habitat of the autumn population. ?

Recent landings from the Japan Sea (including the northwestern ~~coast of Kyushu~~) by Japanese, Korean and Soviet boats are estimated to have been about 350 000–400 000 tons (see Table 2.3). The landings of Japan and the Republic of Korea attained to 260 000 tons in the good years of 1963 and 1968 and increased to 300 000 tons in 1972–1974. These catches are mostly from the winter and autumn populations, while the summer population occupies a very minor position, contributing probably some 10 000–20 000 tons to local landings. The winter population is mainly distributed along the coast of Honshu, Japan, while the autumn population tends to be distributed in the north of the offshore front toward the continent. The breakdown of catch statistics by population and by locality is shown in Figures 2.6 and 2.7 (a) and (b) and Table 2.6. From these figures it is clear that the catch from the winter population does not show any pronounced trend, but undergoes minor fluctuation between 50 000–140 000 tons, averaging around 95 000 tons. Since the catch has not increased in spite of an increase in fishing effort, the size of this population has probably recently decreased. In contrast to this, the catches from the autumn population which reached 120 000 tons in 1963 have increased very rapidly since 1968 to the peak yield of 258 000 tons in 1972. These increases have been due to first an abrupt development of the Korean fishery in 1955 and the immediately following years, and second, increased exploitation of offshore resources by Japan since 1966. Before such an exploration of offshore fishing grounds, the autumn population was fished only when it nears the shore around Oki Islets and Tsushima on its southern migration. The catches of inshore fishing fluctuated between 700 and 5 000 tons during 1951–1964 and about 10 000 tons in average for 1965–1970. The catches from the autumn population prior to 1969 were mostly by Korean boats. Both Japanese and Korean boats were then fishing only a limited small portion of this huge stock. Since 1970 this inshore catch has tended to decrease with a range between 3 000 and 6 000 tons.

After the exploitation of the offshore resources began, the Japanese catch increased at a rapid rate, but after reaching a peak of over 200 000 tons in 1972 has stayed at a rather consistent level in the past few years. This may be because the fishing activity since 1970 covers not only the central part of the Japan Sea but also near the coast of the Maritime Province of the U.S.S.R., the west coast of Sakhalin and the east coast of the Korean Peninsula. Thus, most of the habitat of this population has been covered by fishing matching the range of its seasonal migration and distribution. It seems, therefore, that there may be no more room for increased exploitation of the autumn population and no more increase of the catch is expected.

2.4.2 CPUE since 1971

Figure 2.8 shows the annual change in the total annual catch, number of fishing days and catch per day by tonnage classes (10–30, 30–50 and 50–100) of fishing boats.

The small boats of the 10–30 ton class contribute about 4 percent of this offshore fishery. The fishing days per trip were 3–5 days in 1973 but slightly increased to 4–6 days in 1974 and 1975. The activity of these boats is concentrated in the area extending from the north of Oki Islands to the Yamato-tai Bank (south of lat. 40°N). Thus, the CPUE of this class represents the size of the accessible stock in the southwestern to central Japan Sea. The annual catch per fishing day has decreased from 0.67 tons in 1971 to 0.49 tons in 1974 (the record of 0.58 tons for 1975 was due to an exceptionally large size of the summer population of that year).

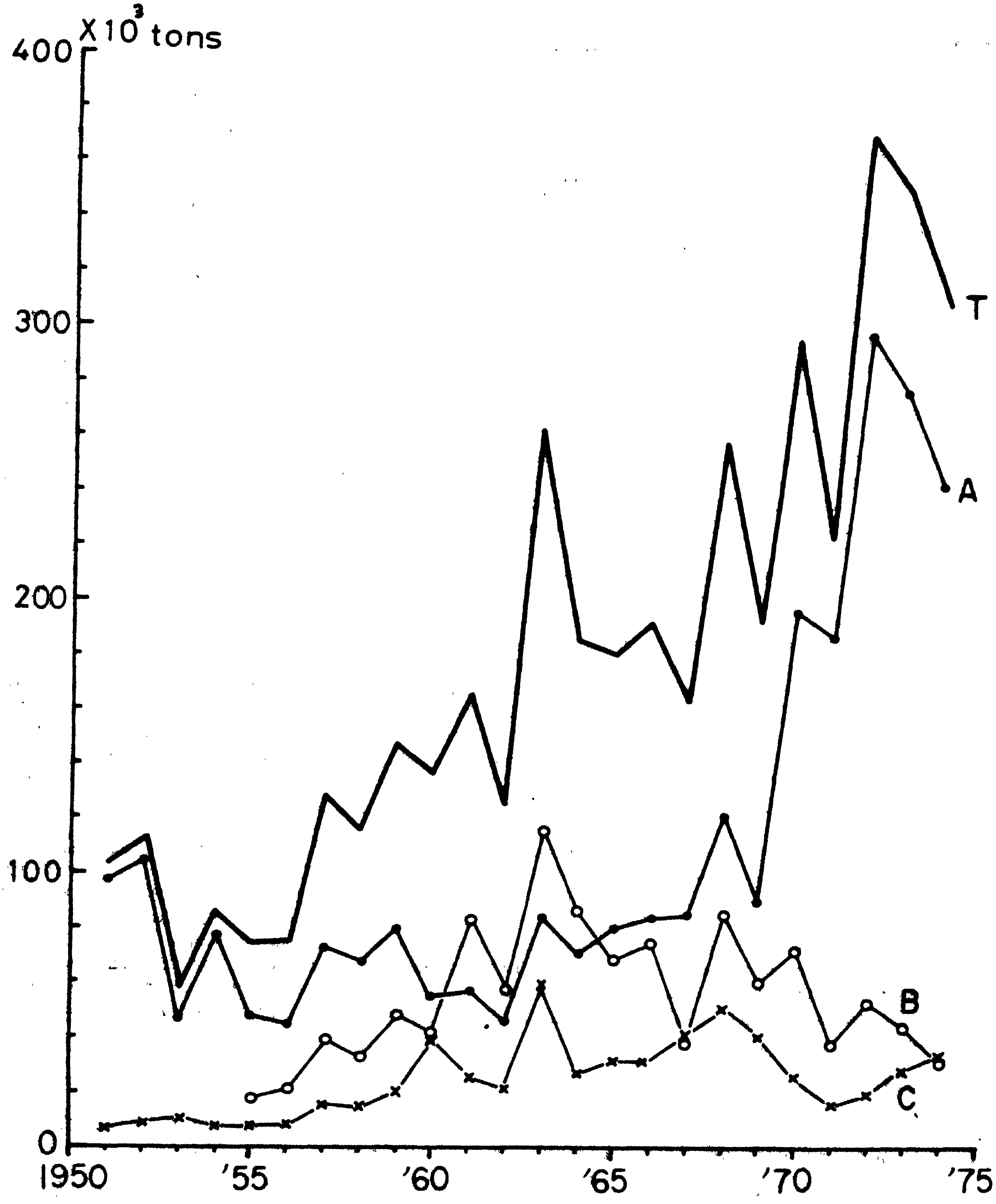
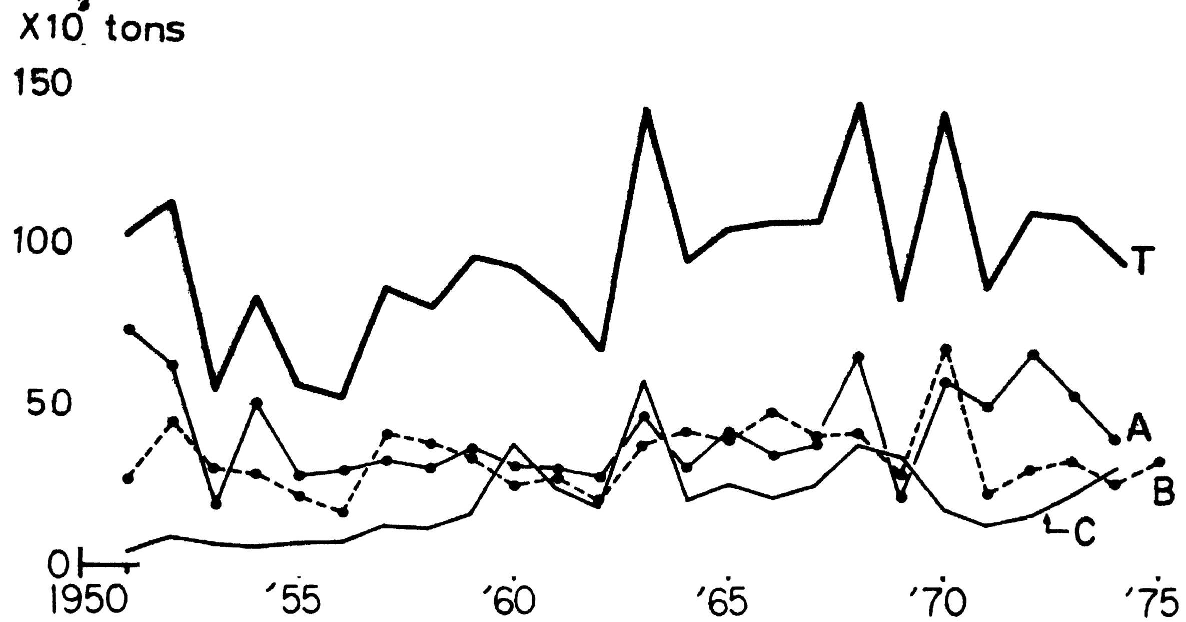


Figure 2.6 Catches of Todarodes pacificus in the Japan and East China Seas. A: Honshu and Hokkaido (Japan), B: East coast of South Korea, C: Northwest coast of Kyushu (Japan), T: Total



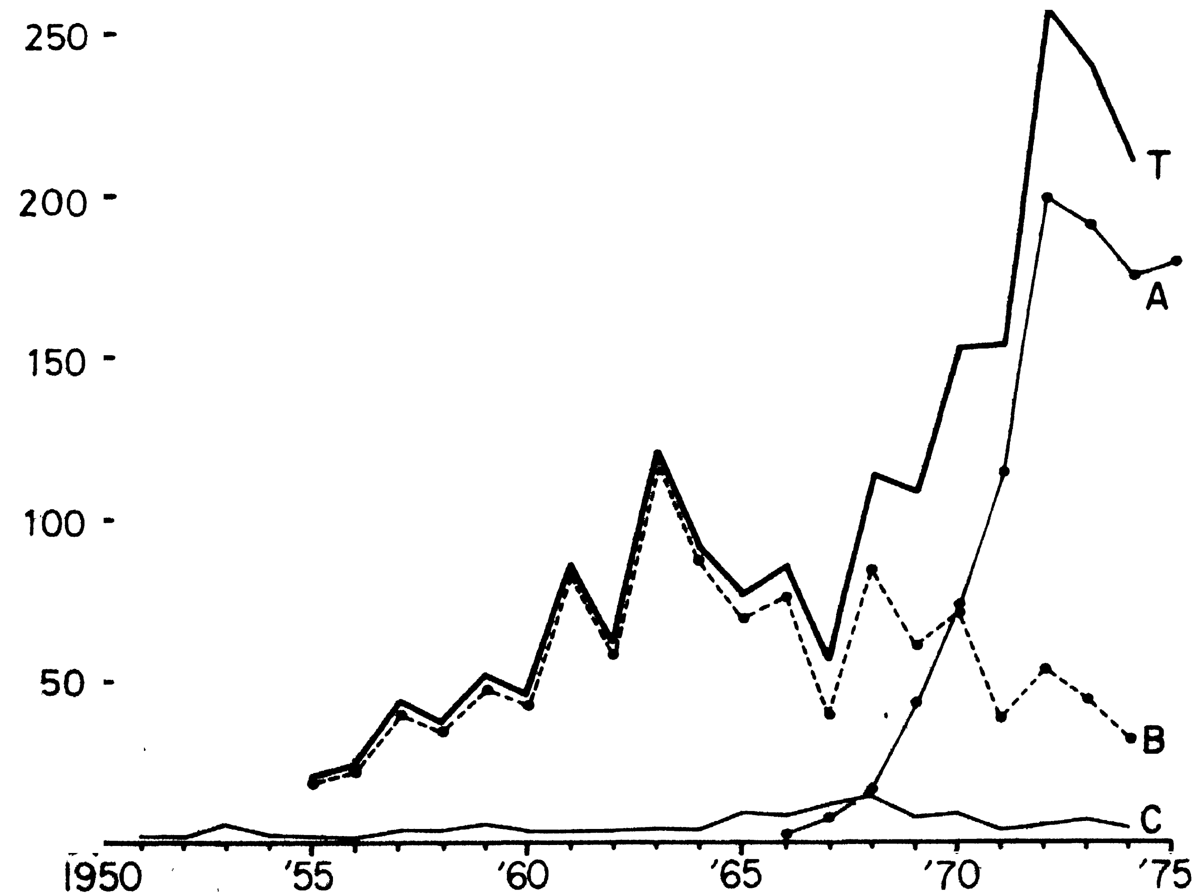


Figure 2.7a Catches from the winter population in the Japan Sea. A: West coast of southern Hokkaido, B: coast of Honshu, C: northwestern coast of Kyushu (excluding Tsushima, Sept.-Nov.), T: Total

Figure 2.7b Catches from the autumn population in the Japan Sea. A: Offshore (Japan, year round), B: coast of South Korea (Korea, year round), C: coast of Tsushima (Japan, Sept.-Nov.)

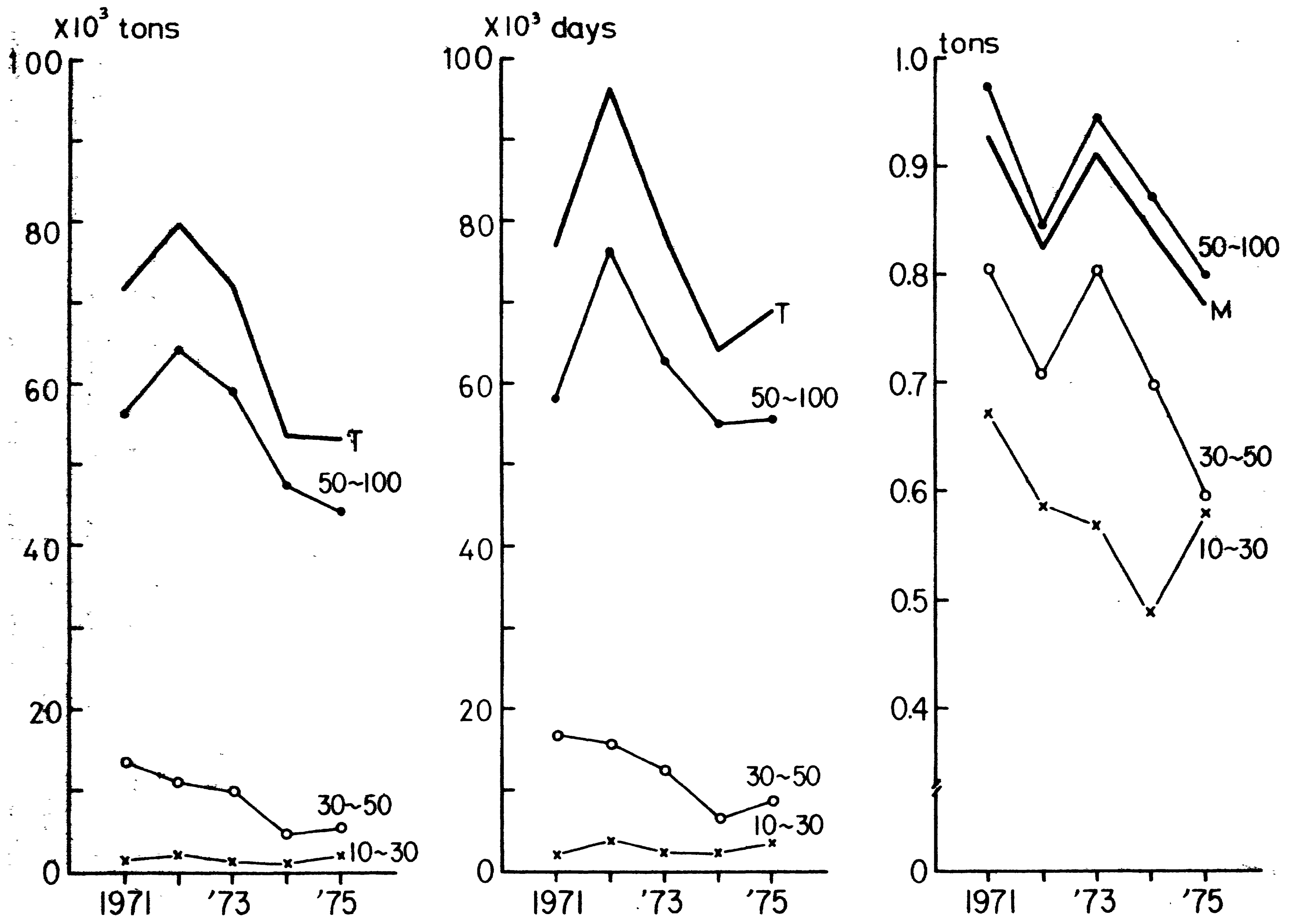


Figure 2.8 Amount of catch (left), numbers of fishing days (centre) and catch per fishing day (right) by tonnage class of boat in the offshore area in the Japan Sea.
——: Total, -X- 10–30 tons, -o- 30–50 tons, -o- 50–100 tons

The total fishing days for 30-50 ton class tend to decrease since 1971 probably because some vessels were rebuilt, and entered a large size-class. The boats of this tonnage class have been operating in the same area as the above mentioned class as well as further east off the Korean Peninsula. The fishing days per trip were 5-8 until they slightly increased in the recent years. Catch per fishing day ranged between 0.7 and 0.8 tons for 1971-1974 but has decreased to 0.59 in 1975.

As to the 50-100 ton class boats the number of fishing days abruptly increased in 1971 and 1972 followed by a gradual decrease. The boats belonging to this class operate in the offshore area as far north as 45°N. These boats are the most important in the squid fishery in the Japan Sea and contribute some 80 percent of the total catch and fishing days. The length of the trip varies between 5 and 10 days and is tending to increase. The average was 6.1 days in 1971, 6.7 in 1972, 6.6 in 1973, 7.0 in 1974 and 7.4 in 1975. Catch per fishing day fluctuates between 0.80 and 0.97 tons but shows a decreasing tendency in recent years.

From the fact that CPUE has tended to decrease as fishing effort increased since 1971-1972, it can be concluded that the autumn population ~~has been lowered in size in the recent~~ years.

2.4.3 Stock assessment

The squids belonging to the autumn population are subjected to fishing for 7 months from May (when they have reached 17-19 cm in mantle length) to November; they then die after spawning. During the fishing period natural mortality seems to be relatively low and fishing has the most important impact on the population. If this is the case, and if also the catchability coefficient remains constant during the fishing season, then the stock size at the beginning of the season can be determined by de Lury's method from the equation:

$$U_t = q(N_o - K_t)$$

where U_t = catch per day in numbers for the period t,
q = catchability coefficient,
N_o = stock size (in number) at the initial time of fishing,
K_t = cumulative catch in number up to the beginning of period t.

The monthly catch per day in Table 2.7 is plotted against the cumulative catch in Figure 2.9. The data for May and June are omitted because there may be recruitment of shoals in these months. These gave the regression equations:

July-November 1972: $y = 4\,032\,404 - 20.997x$
July-November 1973: $y = 5\,345\,122 - 35.734x$
July-November 1974: $y = 4\,417\,889 - 26.992x$

From these equations, the estimated numbers at the end of June each year were:

1972: No = 192.0×10^7 squids (421×10^3 tons),
1973: No = 149.6×10^7 squids (313×10^3 tons),
1974: No = 163.7×10^7 squids (326×10^3 tons).

Roughly speaking, the stock size of the autumn population at the end of June for 1972-1974 is about $150\text{-}200 \times 10^7$ squids ($310\text{-}420 \times 10^3$ tons). There may be a considerable recruitment from the winter population from the north in the closing period of the fishing season in November.

The Japan Sea is $1\,300 \times 10^3$ km^2 of which about three fifths, 780×10^3 km^2, excluding the neritic zones along Honshu, Hokkaido and Sakhalin, are estimated to be covered by the habitat of the autumn population. In this offshore region the distribution of shoals is not uniform, but shoals tend to be concentrated in the boundary between the Tsushima Warm

Table 2.7

Catch per fishing day by month for the autumn population in the Japan Sea

Year	Month	Catch in number per fishing day[a]	Estimated catch[b] in weight (t)	Estimated catch[b] in number ($x10^3$)	Cumulative catch in number ($x10^3$)
1972	May	3 201	12 290	88 610	
	June	3 397	30 650	149 150	237 760
	July	3 498	45 720	180 710	418 470
	Aug.	3 043	60 389	186 390	604 860
	Sept.	3 209	51 430	157 330	762 190
	Oct.	1 983	33 903	92 610	854 800
	Nov.	2 386	24 241	67 640	922 440
	Total		258 623		
1973	May	2 312	9 553	55 350	
	June	3 340	32 324	170 310	225 660
	July	4 494	49 232	198 440	424 100
	Aug.	3 841	53 028	178 910	603 010
	Sept.	3 292	50 776	145 620	748 630
	Oct.	2 653	30 640	95 300	843 930
	Nov.	2 278	16 110	46 750	890 680
	Total		241 663		
1974	May	3 987	10 425	77 110	
	June	3 849	25 398	130 180	207 290
	July	3 902	35 950	173 840	381 130
	Aug.	3 203	42 552	160 510	541 640
	Sept.	3 338	40 031	119 100	660 740
	Oct.	2 270	37 143	106 060	766 800
	Nov.	2 473	19 601	53 090	819 890
	Total		211 100		

After Statistic Bureau of Kinki District

The catches in the Korea and Hokkaido areas were estimated from monthly ratio to that in offshore grounds off

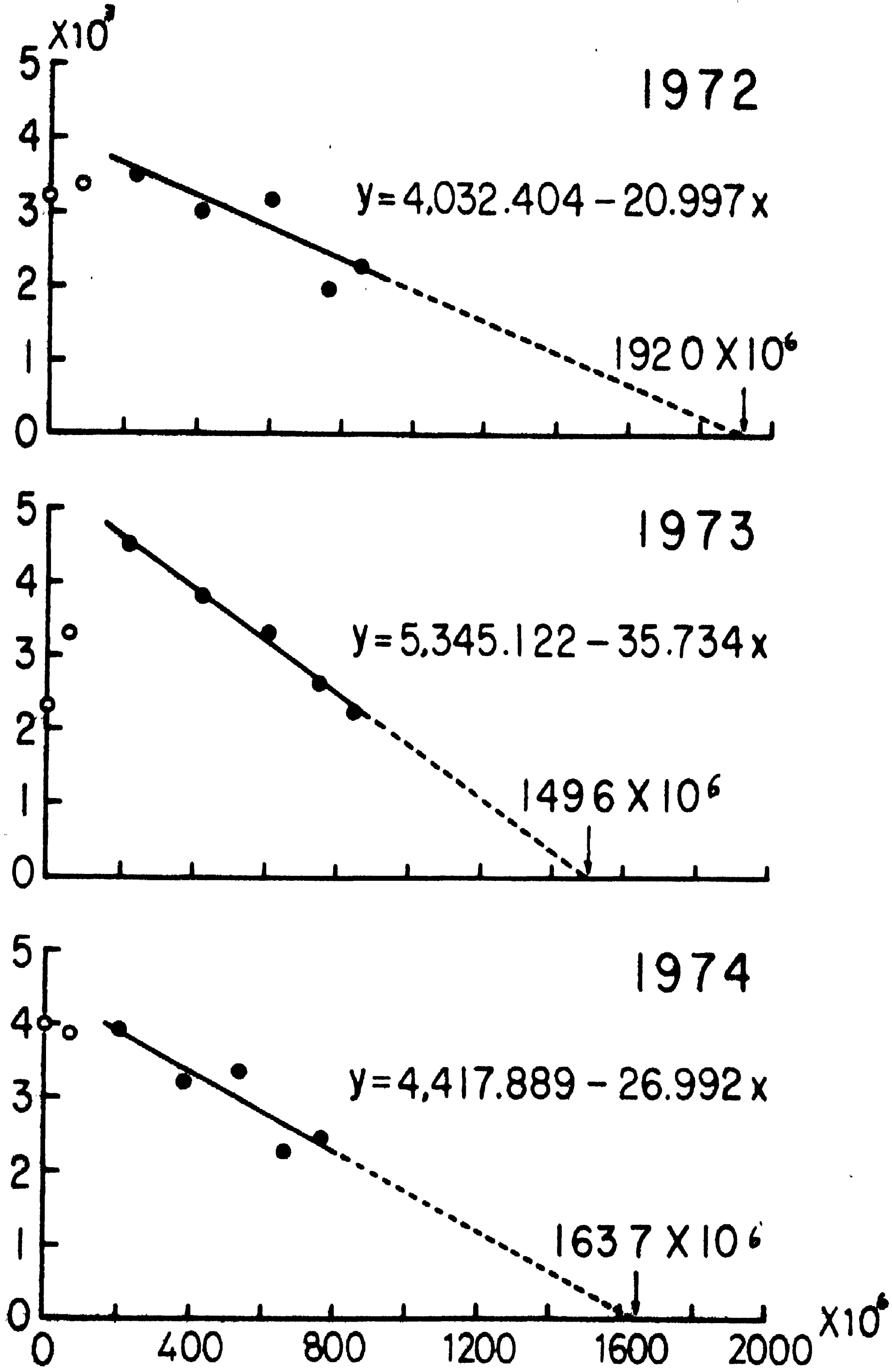


Figure 2.9 Relation between catch per fishing day (y: 10^3 squids) and cumulative catch (x: 10^6 squids) for 3 years.

Current and the subarctic waters as well as the marginal area of the cold water masses. The density and distribution pattern fluctuates from year to year. On the basis of data for 1972-1974, the number of squids per km^2 was calculated to be 2 462 in 1972, 1 918 in 1973 and 2 099 in 1974. Thus it can be said that about 2 000 to 2 500 squid per km^2 are present in the offshore waters in the Japan Sea at the initial period of the fishing season at about the end of June.

As was mentioned above, the autumn population, which was unfished before the late 1960s, has since been subjected to increasing fishing intensity. During the years 1969-1970 it was thought that an increase of fishing effort would result in an increase of catch. However, since the peak in 1972 the catch has shown a tendency to decrease. A decrease has also occurred in the CPUE and in the indices of density at the early periods of northward and southward migration, which have been obtained from detailed data on the distribution of catch and effort (see Table 2.8). Other evidence of changes that might be related to fishing is that the proportion of smaller squid taken in the early period of fishing has increased in recent years, and larval abundance on the main spawning ground around Kyushu seems to be decreasing. Some of these changes may be due to factors other than fishing, and at present the interrelation between larval abundance and abiotic factors is not clear. However, it is not expected that catches from the autumn population will increase in the near future.

2.5 Other Cephalopod Resources in Japan

2.5.1 Sepiid cuttlefish

About 20 species of cuttlefish belonging to the family Sepiidae are known from Japanese waters. Sepiids generally live on the bottom and therefore are caught by bottom trawlers of various sizes. Sepiids are also incidental catches of fixed-net, boat seines and beach seines etc. and also subjected to angling. A large coral-reef species, *Sepia latimanus*, is taken by

In spite of the fact that two large species, *Sepia pharaonis* Ehrenberg and *S. aculeata* Férussac and d'Orbigny, are commercial species in the southeast Asian area, they do not yield significant catch in Japan. Wherever and whichever the medium and small species are fished, they are utilised for food for the local people.

The most important species of the sepiid family is *Sepia esculenta* followed by *S. lycidas* and *Sepiella japonica*. The largest catch of these cuttlefish has been taken in the Seto Inland Sea where tremendous numbers of small-sized trawlers (e.g., 1 238 485 trips by 12 325 boats in 1974), boat seiners (e.g., 844 864 trips by 76 316 boats) and fixed-net (or trap-net) are operated. Usually half of the annual catch of cuttlefish is taken from this (Table 2.9).

The trawl fishery operated in the East China and Yellow Seas also lands large amounts of cuttlefish. Among the catch from these seas some 70 percent of cuttlefish is *Sepia esculenta* (Okada and Otaki, 1955). Using this value, the catches of *S. esculenta* by pair- and bull-trawlers operating in the East China and Yellow Seas have been estimated (Table 2.10). (For the year after 1968 decapod mollusca catches are not broken down to Sepiids and other squids in statistic of MAF.) The catches of the second most abundant Sepiid, *Sepiella japonica* have also been estimated on the basis of statistics for 1959-1964 given by Nakashima and Shindo (1972).

The population of *Sepia esculenta* seems to be composed of a few local subpopulations. The probable grouping of *S. esculenta* populations in the East China Sea region was established by Okada (1957) and in Tokyo Bay by Koito, *et al.* (1956), but the exact segregation of subpopulations of *S. esculenta* has not been firmly established.

Table 2.8

Population index and density index of the autumn population of *T. pacificus* in the Japan Sea

Year	Early June (early period of northward migration)		August - early September (early period of southward migration)	
	P	Φ	P	Φ
1971	100.9×10^3	58.0	67.2×10^3	28.6
1972	61.0	36.7	66.6	28.4
1973	38.7	22.7	71.9	30.6
1974	32.7	23.6	57.3	24.4
1975	40.3	26.9	49.3	21.0
1976	29.6	19.3	29.3	14.6

Note: $P = \sum Ai \cdot \Phi i$

where, P = population index, Φ = density index and A = area index

The area subjected to calculation is:

East of long. 130°30'E, lat. 36°-42°N for early June and East of long. 130°30'E, lat. 36°- 45°30'N for August to early September

Table 2.9

Production of Sepiid cuttlefish from Seto Inland Sea, East China and Yellow Seas (1965-1974) (Percentage from each region in brackets)

Year	Total cuttlefish catch in Japan	Cuttlefish catch in Seto Inland Sea	Cuttlefish catch in East China and Yellow Seas
1965	20 394	6 314 (31.0)	10 263 (50.3)
1966	15 421	7 810 (50.6)	4 490 (29.1)
1967	15 736	7 437 (47.3)	4 421 (28.1)
1968	15 348	8 733 (56.9)	1 744 (11.4)
1969	16 740	11 030 (65.9)	1 177 (7.0)
1970	14 740	9 510 (64.5)	1 786 (12.1)
1971	17 913	9 711 (54.2)	3 053 (17.0)
1972	15 090	7 895 (52.3)	1 538 (10.0)
1973	12 141	7 647 (63.0)	2 085 (17.2)
1974	17 169	9 667 (56.3)	2 163 (12.6)

Table 2.10

Estimated catches of *Sepia esculenta* and *Sepiella japonica* by pair- and bull-trawlers operated in the East China and Yellow Seas (1958-1967)

Year	Total decapod mollusca	Sepiids (A)	*S. esculenta* (estimated)[a]	*S. japonica* (estimated)[b]
1958	15 613	5 117	3 582	325
1959	15 374	4 844	3 391	250[c]
1960	16 419	6 485	4 540	250[c]
1961	14 982	5 990	4 193	435[c]
1962	13 956	5 859	4 101	250[c]
1963	13 008	4 586	3 210	731[c]
1964	18 818	7 871	5 510	129[c]
1965	19 141	8 759	6 131	555
1966	22 023	3 257	2 280	206
1967	20 214	2 861	2 003	182

a/ A x 0.7

b/ Based on the percentage of *Sepiella japonica* derived from the paper by Nakashima and Shindo (1972)

c/ Figures given by Nakashima and Shindo (1972)

2.5.2 Loliginid squids

Myopsid squids belonging to the family Loliginidae are extensively utilised for local consumption. Small species are usually more localised and their statistics broken down to species level are not easily available. A large species, Doryteuthis bleekeri, is distributed along almost the whole of the Japanese coast, excluding the northern part of Hokkaido the southern small islands. Another large species, Loligo edulis (with the western Japan Sea subspecies budo) is more or less restricted to western Japan. Sepioteuthis lessoniana is caught everywhere under the influence of the warm water current. Unlike the family Sepiidae, the species belonging to the family Loliginidae are never discriminated in statistics even to the family level - they are always classified in the entry "other (or miscellaneous) squids".

Doryteuthis bleekeri had been caught from shoals that come into inshore waters for spawning by fixed-net and jigging until this species recently became an object of trawl fishery (Danish seiners) in the sea area extending from off the Ibaraki-Fukushima Prefectures (eastern Honshu) up north to the southern coast of Hokkaido. Based on an observation on specimens trawled from off the Ibaraki-Fukushima Prefectures, Matsui (1974) found that the spawning takes place there in the period from late December till May. The catches taken off the Fukushima Prefectures are from immature squid shoals staying deeper than 150 m during the period from September to November. The spawners come up shallower than 150 m (or above 10°C) by December. The spawning shoals are trawled more frequently off the Ibaraki Prefecture but occasionally off the Fukushima Prefecture. Information on catches of Doryteuthis bleekeri by four sample trawlers in the seas off Ibaraki-Fukushima Prefectures, according to depth and fishing ground, is shown in Table 2.11.

On the coast of Hokkaido, D. bleekeri has been most abundantly caught in the sea area extending from the Tsugaru Straits to the Japan Sea coast (Table 2.12). The fishing lasts from February to July with the peak at April-May. The squid are taken by fixed-net and blanket-net. The catches in the early part of the fishing season consist of immature squid, but those in the later part are sexually mature. Growth, maturity, fatness, spawning, migration and relation to abiotic environment of this squid of this area are well reviewed by Araya and Ishii (1974) and Ishii and Murata (1976).

Another large species, Loligo edulis (which has frequently been referred to as Doryteuthis ki Wakiya and Ishikawa) plus subspecies L. edulis budo Wakiya and Ishikawa are abundantly all the year round by jigging, trawling, fixed-net, and purse and boat seines in the East China Sea, Tsushima Straits and the western part of the Japan Sea.

On the west coast of Kyushu, 88 percent of L. edulis (+ budo) catches are landed in Fukuoka, Saga and Nagasaki Prefectures, the latter being the most important, producing 73 percent of the total landing. Jigging takes 73 percent of the catches and fixed-net 17 percent.

As the statistics have never been broken down to species, the catches by species are not always clear (Table 2.13), but it is estimated on the basis of statistics for the recent 10 years that about 10 000 tons of L. edulis (+budo) are caught by various fisheries on the west coast of Kyushu, 10 000 tons by pair- and bull-trawlers in the East China Sea and 1 000 tons by trawl in the western part of the Japan Sea. Among them, the catches by various fishing gears in neritic fishing grounds show considerable year to year fluctuations, but those by offshore trawling have been relatively consistent (Y. Shojima, pers.comm., 1977).

2.5.3 Oceanic squids: selected species

Besides the neritic squids (mostly of the family Loliginidae) and cuttlefish (Sepiidae), ...al oceanic species belonging to the family Ommastrephidae have been traditionally utilised. Within this family, other species of the sub-family Ommastrephinae, which may be more of an oceanic nature, have never been commercially fished. However, the recent depletion of Todarodes pacificus around Japan has triggered the commercial exploitation of hitherto u utilised (or only slightly utilised) oceanic squids in the Northwest Pacific (Table 2.14).

Table 2.11

Catches and CPUE of four sample trawlers for *Doryteuthis bleekeri* in the sea off Ibaraki and Fukushima Prefectures, Honshu (After Matsui, 1974)

				Oct. 1967- April 1968	Sept. 1968- April 1969	Sept. 1969- March 1970
Fishing ground	Off Fukushima Prefecture (North)	A	Total	132	1 744	1 128
			CPUE	11	6	24
		B	Total	2 820	5 677	10 520
			CPUE	21	13	48
		C	Total	2 449	2 149	6 346
			CPUE	12	21	28
		D	Total	10 095	931	5 619
			CPUE	49	19	32
	Off Ibaraki Prefecture (South)	E	Total	10 743	778	35 665
			CPUE	68	24	143
Depth (m)	0-74		Total	236	1 009	661
			CPUE	5	10	39
	75-149		Total	6 139	5 736	36 373
			CPUE	24	25	74
	150-224		Total	12 795	3 702	13 592
			CPUE	51	40	84
	225-299		Total	7 745	827	9 546
			CPUE	49	18	38

Table 2.12

Catch statistics of Doryteuthis bleekeri in Hokkaido[a] (1965-1974)

Year	Catch
1965	2 736
1966	2 671
1967	2 781
1968	1 709
1969	1 398
1970	1 064
1971	2 972
1972	3 312
1973	3 388
1974	4 345

a/ Sums of catches in Aomori Prefecture (Honshu), Oshima, Hiyama, Shiribeshi, Rumoe and Soya Provinces (Hokkaido)

Table 2.13

Catches of "other squid"[a] by pair- and bull-trawlers operated in the East China and Yellow Seas (1958-1967)[b]

Year	Total decapod mollusca	"other squid"
1958	15 613	10 496
1959	15 374	10 530
1960	16 419	9 934
1961	14 982	8 992
1962	13 956	8 097
1963	13 008	8 422
1964	18 818	10 947
1965	19 141	10 382
1966	22 023	18 766
1967	20 214	17 353

a/ The entry "other squid" includes all decapod cephalopods other than sepiid cuttlefish. The breakdown to the species has not been known

b/ The statistics after 1968 are not broken down even to "cuttlefish" and "other squid"

Table 2.14

Landing of two oceanic species (*Ommastrephes bartrami* (Lesueur) and *Onychoteuthis borealijaponica* Okada) in comparison to the common squid, (*Todarodes pacificus* Steenstrup) in Hokkaido and NE Honshu (after Murata, unpublished MS)

Year	*Todarodes pacificus*	*Ommastrephes bartrami*	*Onychoteuthis borealijaponica*
1968	492 973	-	-
1969	337 132	-	-
1970	178 994	-	-
1971	111 971	-	2 200
1972	172 206	-	750
1973	38 317	-	60
1974	48 416	17 000	5 000
1975	77 249	45 000	-
1976	<10 000[a]	90 000[a]	?

a/ Estimated

Thus, surveys of oceanic species became necessary for estimating the exploitable stock size. The species subjected to initial investigation by Japan were Ommastrephes bartrami (Ommastrephidae), Onychoteuthis borealijaponica (Onychoteuthidae) and Gonatopsis borealis (Gonatidae) that occur with Todarodes pacificus in the Northwest Pacific off northeast Honshu and Hokkaido in the summer

2.5.3.1 Ommastrephes bartrami (LeSueur) アカイカ

This species closely resembles the Japanese common squid, Todarodes pacificus, but belongs to a different subfamily among the family Ommastrephidae. The general shape of the body is similar to T. pacificus but O. bartrami is distinct from it by having (a) lateral pockets in the funnel groove; (b) sharp teeth at every 90° on the horny ring of tentacular suckers and (c) photogenic tissues embedded in the integument of the ventral mantle. O. bartrami attains a length of slightly over 40 cm (mantle length).

The major habitat of this species is the near-surface layer in the warm-water oceanic environment of the world oceans. It seems to be particularly abundant in the sub-tropical and temperate North Pacific. While it is a warm-water species this squid frequently migrates up north to the northern rim of the mixing water area off the northeast coast of Honshu where big shoals are aggregated as they meet the cold subarctic waters. There they are frequently eaten by sperm whales (Okutani et al., 1976).

The investigated specimens were mostly sexually immature and were at the feeding stage. The ecology and behaviour of spawning shoals have never been clarified except for an incidental find of a mature female in a far offshore station off the Izu Islands in late autumn (Fujitomi, personal comment). The methods of identifying the larvae of this species, and of separating them from rhynchoteuthions of closely related species (Okutani and Watanabe, 1977) are not yet well established. Therefore, the larval ecology of this species is unknown at present.

Following the recent depletion of the Pacific population of Todarodes pacificus, this species became the most important target of the squid jigging fishery. The fishing grounds are formed in the mixing (transitional) area between warm Kuroshio and cold Oyashio water off northeastern Honshu, when this warm-water species migrates up to the northernmost limit of its distributional range.

2.5.3.2 Onychoteuthis borealijaponica (Okada) ツメイカ

This species is the North Pacific congener of Onychoteuthis banksii (Leach) with which it had been synonymised until Okada's name was recognised to be valid and revised by Young (1972). The species is very common in an oceanic-pelagic environment in the North Pacific except in the central water mass in which it is replaced by O. banksii. O. borealijaponica attains about 28-29 cm mantle length and is characterised by having large fins, many nuchal folds and more than 25 hooks in tentacular

The early larvae of this species have been reported from the California Current (Okutani and McGowan, 1969) and the southwestern waters off Japan (Okutani, 1969; Yamamoto and Okutani 1975). The distribution range of this species at maturity is extended to the Northwest Pacific from the warm water area off Japan up north to the mixing (transitional) water area off northeastern Honshu and Hokkaido. This species is sparsely distributed in the warm water region, but tends to be concentrated to the southern rim of the Subarctic Water Mass near the Southern Kurile Islands during the summer (Murata et al., 1976; Murakami, 1976). In the cold season the shoals seem to migrate down south to the warm counter-current area. In the Northeast Pacific, this species is known from the California Current (Okutani and McGowan, 1969; Young, 1972) in the eastern part of the distributional range, but the linkage between the Northwestern Pacific stock and the Northeastern Pacific stock is not clear at present. However, the recent investigation on the distribution of exploitable stocks of this species revealed that it extends far offshore.

The species is a true surface living species and has frequently been jigged or netted at the surface particularly at night or occasionally found having jumped aboard the vessel.

The recent commercial exploitation of this species has been accelerated by the recent pronounced depletion of Todarodes pacificus in the Pacific since 1970. The fishing ground for this species may sit only a marginal area of the vast distributional range. Therefore, the fluctuation of catch may be due as much to changes in the proportion of population that immigrates into the reach of fishing activity as to fluctuation of year-class sizes.

2.5.3.3 Gonatopsis borealis

Squid belonging to the family Gonatidae have a common squid-like appearance and are all oceanic species. The most important characteristic of this family is that all the arms have four series of suckers of which the inner two rows grow hooks (except in Arm IV). The largest genus in this family, Gonatus, is characterised by an enormous hook on the tentacle. On the contraty, the genus Gonatopsis is characterised by the lack of tentacles in the adult stage despite the fact that larvae retain tentacles as in other members of the family (Okutani, 1966). The third genus, Berryteuthis, which now contains two species, is characterised by a slender tentacular manus that carries minute suckers in multiserial rows (about 16-20).

G. borealis attains about 25 cm mantle length and is characterised by large fins, soft integument, reddish-purplish colouration throughout and strong arm hooks. Larvae are very common in the surface layer of the Subarctic water area whereas the grown animals seem to occupy epi- to mesopelagic habitat of the open oceans. The species is found exclusively in the Subarctic Water Mass extending from the Pacific coast of northeastern Honshu, the surrounding seas of Hokkaido, Kurile Islands and the Aleutian Archipelago besides the Bering Sea, Alaska and Oregon-California coasts. The fully mature females which are impregnated with spermatophores in the internal surface of the mantle have frequently been collected From this evidence, together with abundant occurrence of larvae, it is clear that this species is propagating within the cold Subarctic water.

This species is one of the incidental catches in the fishery for T. pacificus in the Pacific waters off northeastern Honshu and Hokkaido.

The "fishing ground" for this species may be the southwestern fringe of its distribution range.

2.5.3.4 Estimates of potential

For these three species sufficient investigations have been made to make a first attempt to estimate the potential yield, at least from the accessible part of the stocks. The main bases for the estimates have been surveys and comparison with the density and yield of T. pacificus.

Surveys for squid have been carried out by the Hokkaido Regional Fisheries Research Laboratory in the area west of 152°E and 40-45°N since 1968. The detailed results, expressed as numbers of squid caught per one jigger per hour, have been set out in charts in Murata et al. (1976) for surveys from 1968 to 1974. As an example, catch rates observed in 1973 are shown in Fig. 2.10. On these charts, contours were drawn of equal catch rates, and from these an index of abundance P of the population (in terms of numbers) in the veyed area was calculated as:

$$= \sum n_i \, p_i$$

where for each contoured level of abundance (0-1 squid per jigging, 1-5 ......, etc.) n_i = of 10' x 10' squares within that contour, and p_i = mean catch rate. The density in

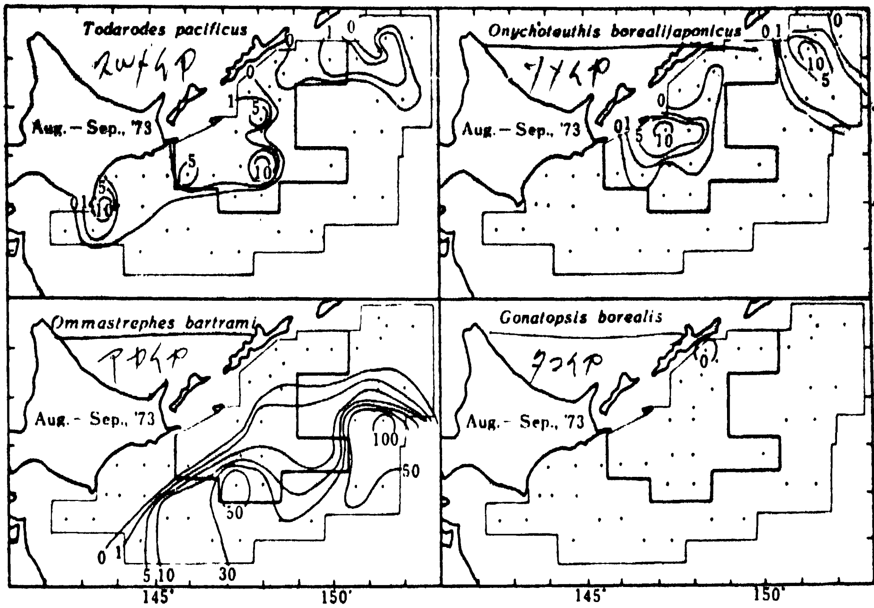


Figure 2.10 Densities of distribution for each squid per one jigger an hour in September 1969 and in August-September of 1973

the surveyed area was then calculated as:

$$d = P/n$$

where n = total number of 10' x 10' squares in the surveyed area.

These indices are given in Table 2.15. They are not entirely adequate because they are both affected by changes in the area surveyed. Any increase in the extent of the area will clearly increase P_1. On the other hand if the additional area surveyed lies outside the distribution of the stock, then the increase in P will be negligible and d will decrease. A correction for this has been made in the data for 1973 and 1974 in which the figures in brackets are based in a reduced survey area which corresponds to the area surveyed in 1968 and 1969. These corrections cannot, however, deal with the problem that there are practical limits on the size of the survey area, and that for the species with wide oceanic distribution, the survey includes only a part of the whole population. This can affect year-to-year comparisons if there are differences in distribution or migration pattern from year to year, but are likely to be more serious in attempting species-to-species comparison. For example, coverage for August-September 1973 suggests that the survey may include most of the population of Todarodes pacificus and Onychoteuthis borealijaponica, but probably only the southern extremity of the distribution of Gonatopsis borealis, and the northwestern part of that of bartrami. The indices may therefore give a reliable measure of the relative the first two species, but underestimate that of the latter two relative to

possible source of bias in using these indices for inter-species comparisons is in the vulnerability of each species to the gear, so that at any given survey position the same catch rate could represent different real densities of squid at that position. Murata et al. (1976) point out that O. bartrami is more accessible to jigs than T. pacificus, so that the indices may overestimate its relative abund.

It may also be noted that the indices have been calculated in terms of number, not weight. The average weight of an individual O. bartrami is some 3-5 times that of an individual T. pacificus, while Onychoteuthis is 1.5 to 2 times as big. Therefore the indices should be increased by this factor to provide a correct measure of the relative abun in terms of weight (though the average weight of T. pacificus may have been reduced of the high level of fishing).

An interesting feature of Table 2.15 is that increase in Ommastrephes (and to a lesser extent Onychoteuthis) between 1969 and 1973 matches the decrease in Todarodes. Since the data are from research surveys there is no question of selection or change of tactics by th fishermen, so that the changes are real. It is, however, not certain whether the increase : Ommastrephes in the survey area is an increase in the whole population, or a greater extens: of the large oceanic population into the survey area. Nor is it possible at this stage to distinguish between the hypotheses that (a) the two events are independent, (b) that there has been a natural environmental change favouring Ommastrephes, or (c) that the events are caused wholly by the fishery, Ommastrephes increasing to fill the niche left partly vacant by the depletion of Todarodes.

Table 2.15

Stock size index (P) and density (B) of four oceanic squids based on synoptic exploratory fishing investigations for 1968-1976 (Murata, MS.)

Months		August - September					
Year		1968	1969	1973	1974	1975	1976
Surveyed area a/		275	287	1 083	832	690	842
Todarodes pacificus	P	104.5	80.5	7.8 (5.0)	5.1 (4.9)	21.1	1.0
	B	38.06	28.06	0.72 (1.51)	0.61 (1.84)	3.06	0.12
Ommastrephes bartrami	P	5.6	3.7	144.0 (23.0)	47.6 (3.3)	75.9	139.1
	B	2.05	1.29	13.30 (7.00)	5.72 (1.22)	11.01	16.51
Onychoteuthis borealijaponica	P	8.9	3.4	7.2 (3.5)	40.9 (23.6)	28.5	48.0
	B	3.23	1.17	0.67 (1.08)	4.91 (8.78)	4.12	5.69
Gonatopsis borealis	P	2.5	0	0.0 (0.0)	3.4 (3.3)	0.4	0.4
	B	0.90	0	0.00 (0.05)	0.41 (1.24)	0.06	0.05

a/ Number of 10' x 10' grods

P: x 10^2

The relations of these indices of population size to potential yield depend on the life-
and natural mortality rate. The life-span of Todarodes is one year, and that of
mmastrephes, though not known, is presumed to be the same, which suggests that the relation
'or these (and also the other) species should be the

The observed relation between catch and abundance index for Todarodes is gi
Figure 2.11. The data fit, as expected, a proportional line, with the relation:

Catch (thousand tons) = 4.5 x population index P

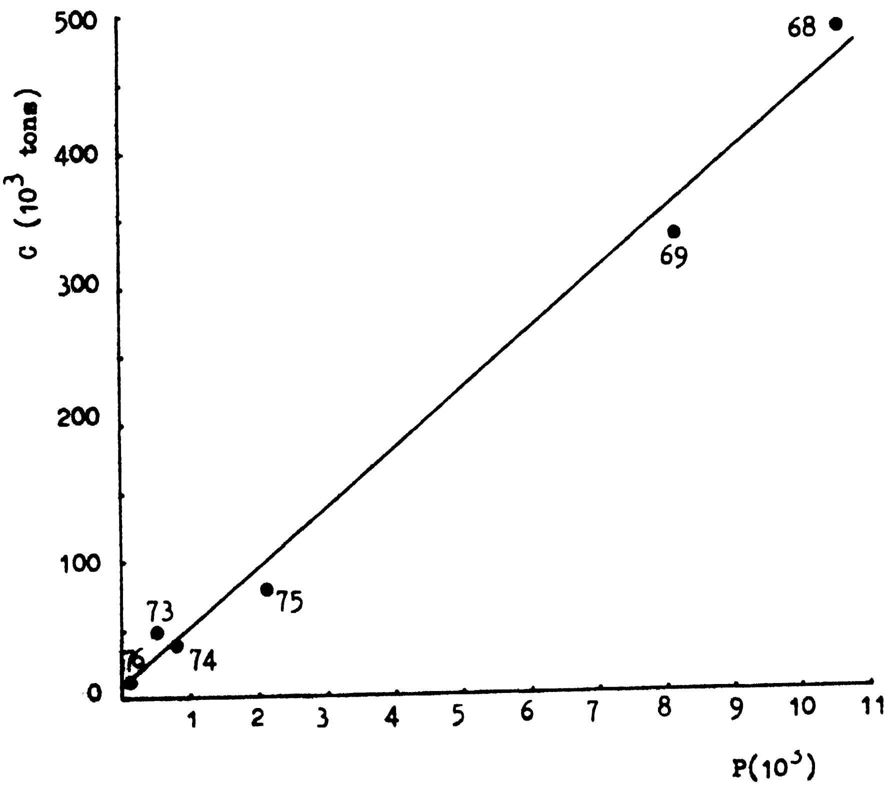


Figure 2.11 Relation between catch (C) and population index (P) of summer season in the waters off the Pacific coasts of n Hokkaido. C is based on Table 2.14 and P on Table 2.15, respectively.

Equation for the regression line: C = 45.05P + 2 093

With the reservations noted above, in which some of the sources of bias (catchability and weight) probably work in opposite directions, the same relation can be used for the other species, at least in respect of that part of the populations that occur in the surveyed areas Accepting that there may be procedural errors and biases of perhaps a factor of two in either direction and rounding off rough estimates of potential catch, using the mean figures of population index from Table 2.15 are:

	Mean P	Potential Catch
	69.3	150 000 - 600 000
Onychoteuthis borealijaponica	22.8	50 000 - 200 000 125,000
Gonatopsis borealis	1.1	2 000 - 9 000 5.500

It must be stressed that these estimates only concern the potential yield for that part of the total populations that come within the survey area. The total population may be larger. For example, the presence of large larval populations of Gonatopsis borealis (Okutani, 1966) suggests the existence of much larger populations in the vast distribution range beyond the reach of present fishing activity.

2.5.4 Oceanic squid: other species

2.5.4.1 Symplectoteuthis oualaniensis (Lesson)

Another member of the family Ommastrephidae, Symplectoteuthis ovalaniensis is believed to contain a large stock in the oceanic environment in the Indo-Pacific region. This species is very similar to Ommastrephes bartrami but differs from it by having (a) an oval patch of photogenic tissues on the anterodorsal region of the mantle and (b) a muscular fusion at the mantle-funnel connectives. The females grow to 30 cm mantle length but the males only to about 18 cm mantle length. The rhynchoteuthion larvae are abundant in plankton collections in the waters extending from the southeastern waters of Japan (Yamamoto and Okutani, 1975) to the South China Sea (Shojima, 1972). According to investigations on the populations around the island of Taiwan, three seasonal subpopulations seem to exist, separable in terms of size-maturity relationship (Tung, 1976). The distribution range covers the whole tropical to subtropical Indo-Pacific area including the Kuroshio waters around Japan, but commercial exploitation on this squid has only been carried out in Okinawa (Japan) and Taiwan. Although some aspects of fishery biology on this species have recently been contributed by Tung et al. (1973) and Tung (1976), nothing has yet been established concerning stock size assessment. The only catch records available at three landing ports are given in Table 2.16.

2.5.4.2 Thysanoteuthis rhombus Troschel

This oceanic squid which grows to 60 cm mantle length does not form a large shoal but is usually found swimming near the surface in groups of two or several individuals. The distribution range covers the warm water areas of the whole world. The floating egg mass and early larvae have been recorded in the Mediterranean Sea (Sanzo, 1929) and the Northwest Pacific near Japan (Yamamoto and Okutani, 1975; Misaki and Okutani, 1976). It has occasionally drifted ashore both on the coasts of the Pacific and the Japan Sea (Nishimura, 1966).

This species was not commercially exploited until recently. The fishery began in 1962 in Hyogo Prefecture (the Japan Sea side). Until 1966 T. rhombus was jigged from the boat while drifting, but since 1967 a single jig connected to a drifting float has been used (Nasumi, 1975). The catch statistics for this species is only for Hyogo Prefecture (Table 2.17).

Table 2.16

Landings (in kg) of S. oualaniensis at certain ports in the islands of Taiwan and Okinawa (Tung et al., 1973; Ryukyu Fisheries Experimental Station 1971)

Year	Taiwan		Okinawa
	Kaohsiung	Hengchun	Itoman
1966	*	*	42 014
1967	*	*	47 659
1968	*	*	41 501
1969	*	*	29 907
1970	149 556	6 414	49 166
1971	106 566	3 837	*
1972	28 219	1 181	*

* No published data are available

Table 2.17

Catch statistics of Thysanoteuthis rhombus in Hyogo Prefecture (Nasumi, 1975)

Year	Catch
1962	2.0 tons
1963	0
1964	232.5
1965	5.0
1966	7.0
1967	619.8
1968	0.1
1969	26.7
1970	66.8
1971	62.5
1972	516.0
1973	305.0
1974	44.2

2.5.4.3 <u>Berryteuthis magister</u> (Berry)

<u>Berryteuthis magister</u> (Berry) is another abundant gonatid in the Subarctic Pacific and the Bering Sea. The species attains 25 cm mantle length. This species spends an epipelagic life during larvae to juvenile stages but the adult population is bathyal. There is a great deal of evidence on the existence of a huge stock of this type of squid in the area extending from the Japan Sea, the Pacific coast of Honshu and Hokkaido, the Bering Sea, the Gulf of Alaska down south to the Oregon coast, such as findings from whale's diet (Okutani and Nemoto, 1964) and substantial incidental catches taken by bottom trawls. This species has been rather ignored for human consumption, so that no reliable statistics are available. Ogata, Okiyama and Tanino (1973) reported that all 44 hauls of bottom trawl (including a single unsuccessful haul) undertaken on Oki Shelf, New Oki Bank, Yamato Bank and New Yamato Bank in the Japan Sea were positive for this squid. These trawling operations were reportedly done in the depths between 250 m and 1 200 m. The total number of <u>B. magister</u> then collected was more than 30 000 weighing some 38 tons. The largest catch per haul was 1 320 kg/haul/30 minutes at a depth of 310 m on the Yamato Bank.

2.5.4.4 <u>Watasenia scintillans</u> (Berry) (Enoploteuthidae)

This species attains only 5-6 cm mantle length and lives a meso- to bathypelagic life. The commercial fishery for such a small-size luminous squid is quite unusual. The fishery catches shoals that come up to the shallow water for spawning in the Toyama Bay, Japan Sea, during early summer (Table 2.18). The fishing season and place are very restricted and there is no other place where fishing for this species exists in spite of the fact that a large population is proved to be present in meso- to bathypelagic zones both in the Japan Sea and Pacific coasts along Honshu and Hokkaido. A similar spawning aggregation of bathypelagic species of the same family, <u>Abralia veranyi</u> (Rüppell) was reported by Berry (1926) at Funchal harbour in Madeira.

2.5.4.5 Octopuses

As shown in Table 2.1 some 60 000 to 100 000 tons of octopuses are landed by Japanese fishermen annually. The octopuses are caught by traps (octopus pot and octopus box), bottom long-line, jigging (or hooking), spearing and trawling by various size spectra. The catches
d boiled, dried, frozen, canned, smoked and processed in other

The majority of catches from Honshu (excluding the northern part), the Shikoku and Kyushu regions including the Seto Inland Sea are of <u>Octopus vulgaris</u>. A very small amount of <u>O. ocellatus</u> and <u>O. minor</u> may be included in the statistics for these regions. On the other hand, the major portion of catches from northern Honshu and Hokkaido consists of a a giant octopus, <u>Paroctopus dofleini</u> with small fractions of <u>O. conispadiceus</u> and <u>O. araenoides</u>, but they are never broken down to species in any statistics.

The probable breakdown of octopus catches into two groups is shown in Table 2.19.

3. JAPANESE LONG-RANGE FISHERIES

3.1 <u>Species Exploited by Japan and Statistics</u>

The cephalopod fishery by Japanese fleets in the high sea had been by trawlers until jigging fishing for pelagic species was developed. The major species caught by the trawlers are:

<u>Sepia officinalis</u> Linné (Atlantic, African coast)
<u>Sepia pharaonis</u> Ehrenberg (Indian Ocean, Arabian Sea)
<u>Loligo forbesi</u> Steenstrup (Atlantic, African coast)
<u>Loligo pealei</u> LeSueur (Atlantic, American coast), and
<u>Octopus vulgaris</u> (Atlantic, African coast)

Table 2.18

Landings of *Watasenia scintillans* for the past 15 years
(Toyama Statistic Office, Hokuriku Agriculture Bureau)

Year	Landing in tons
1961	2 533.2
1962	1 733.1
1963	2 347.8
1964	2 595.9
1965	1 737.5
1966	884.6
1967	1 432.8
1968	1 736.6
1969	1 645.8
1970	2 833.4
1971	1 592.7
1972	3 710.1
1973	3 302.5
1974	1 027.0
1975	1 248.0

Table 2.19

Japanese octopuses catches (1965-1974) (tons)

Year	Total octopuses	*O. vulgaris* (+ *O. minor* and *O. ocellatus*)		*P. dofleini* (+ *O. conispadiceus* and *O. araenoides*)	
		Seto Inland Sea	Other areas	Hokkaido	Other areas
1965	78 057	10 565	43 595	20 159	3 738
1966	65 551	9 851	31 020	20 751	3 930
1967	98 130	10 865	63 532	18 567	5 167
1968	102 718	7 740	74 471	17 821	3 686
1969	92 418	7 962	61 110	18 380	4 966
1970	96 127	8 586	59 249	22 371	5 921
1971	49 063	8 990	8 435	26 547	5 133
1972	66 857	8 759	33 895	19 718	4 485
1973	62 278	7 580	28 077	21 519	5 102
1974	76 731	9 166	40 165	23 708	3 692

The incidental catches may include small sepiids and loliginids as well as such ommastrephids ________ *sloani sloani* (Gray) (New Zealand), ________ *sagittatus* (Lamarck) (Atlantic, African coast), *Todaropsis ebalane* (Ball) (Atlantic, African coast) and *Illex illecebrosus* (Lesueur) (American coast). The statistics of Japanese trawl catches are shown in Tables 3.1 3.2.

A finding of a large population by trawlers lead a successful development of jigging fishery for ommastrephids. The targets of jigging fishery are:

Nototodarus sloani sloani (Gray) (New Zealand)
Illex illecebrosus (LeSueur) (Atlantic, North American coast), and
Dosidicus gigas (d'Orbigny) (East Pacific, exploratory)

The incidental catch occasionally includes loliginids and other species of ommastrephids.

3.2 Pelagic Species (Jigging Fishery)

3.2.1 *Nototodarus sloani sloani* around New Zealand

the squids around New Zealand, *N. sloani sloani* is the commercially most important species at present. Annual catches in recent years have been 10 000-20 000 tons (Table 3.3).

On the basis of the mantle length at which females mature and spawn, three size groups of spawners can be distinguished: small (less than 20 cm mantle length), medium (24-28 cm) and large (over 30 cm). Spawning groups can also be distinguished according to the season of spawning, namely the autumn, autumn-winter, spring, and summer-autumn groups. By considering these and other characteristics, it is possible to identify as many as eight component groups of this species around New Zealand (Kawakami 1976, a) (Fig. 3.1), although it is not yet known whether they are really separate stocks.

The data presently available are not sufficient for an assessment of the fishery.

3.2.2 *Illex illecebrosus* off New York and Newfoundland

This is an oceanic species that migrates into the coastal waters of the northwest Atlantic (New York to Labrador) in spring and summer. There are small traditional fisheries in Canada (Pinhorn, 1976) and the U.S.A. (Tibbetts, 1975). It has been known for some time, on the basis of incidental trawl catches off Newfoundland that the stock is large (Squires, 1957; 1959), but only in the last few years has there been a directed fishery by large trawlers.

Catch rates have fluctuated greatly both in commercial fisheries and in trawl surveys (Tibbetts, 1975; Sissenwine, 1976), either because of real fluctuations in abundance or annual changes in availability (*Illex* is not benthic, so it is not reliably sampled by trawls). Surveys in 1975 and 1976 produced imprecise stock size estimates of 100 000-200 000 tons, but in those years the apparent abundance of the stock was substantially larger than in previous years (ICNAF, 1976, page 112; Mesnil, 1977). On the basis of a theoretical estimate that about 40-50 percent of the stock could be harvested safely each year (Au, 1975), ICNAF set a precautionary quota of 60 000 tons on catches in 1977.

A Japanese research vessel carried out exploratory jigging for *I. illecebrosus* in the ICNAF area each year from 1973 through 1976 (Figure 3.2). The results, shown in Table 3.4 are highly variable among years and areas as might be expected in the case of this species. The composition of these catches by size and maturity stage suggest that there are two spawning groups in the stock, namely the small (14-18 cm mantle length) summer spawners and the large (22-26 cm) winter spawners, in conformity with the alternative schedules proposed by Mesnil (1976).

Table 3.1

Cephalopod catches of Japanese high sea trawlers[a] (tons)

Year	1967	1968	1969	1970	1971	1972	1973	1974	1975
Africa, northwest coast	97 063	108 961	75 986	56 453	59 155	59 549	55 952	45 997	33 172
Africa, west coast	7	-	2	-	-	-	-	-	-
Africa, south coast	41	22	151	143	110	313	498	2 828	2 906
North America, northeast coast	6	1 830	0	13 698	11 644	18 271	15 544	16 922	14 556
North America, southeast coast	-	-	-	-	-	2	-	10	774
Other Atlantic	-	-	35	-	44	93	177	67	-
Arabian Sea	2 486	2 420	3 272	2 657	4 557	6 801	5 060	5 723	3 716
New Zealand	-	-	204	353	46	728	4 045	2 999	2 469
Total	99 603	113 233	87 359	73 304	75 555	85 757	81 275	74 592	58 593

a/ Data from the Far Seas Fisheries Research Laboratory; exclusive of North Pacific trawling catch

Table 3.2

Detailed statistics of Japanese high sea trawling (catches in tons)

		1967	1968	1969	1970	1971	1972	1973	1974	1975
A: *Sepia* spp. (mostly *S. officinalis* in the Atlantic and *S. pharaonis* in the Arabian Sea)	Africa, northwest coast	31 672	29 374	24 054	12 325	15 914	21 446	21 196	11 670	7 303
	Africa, west coast	7	–	– 2	–	–	–	–	–	–
	Africa, south coast	9	–	–	–	–	–	–	–	9
	Arabian Sea	2 480	2 399	3 272	2 630	4 557	6 801	4 898	5 359	3 600
	Total	34 168	31 773	27 328	14 955	20 471	28 247	26 094	17 029	10 912
B: *Loligo* spp. (mostly *L. forbesi* in the African coast and *L. pealei* in the American coast)	Africa, northwest coast	11 524	6 650	5 617	4 310	5 102	4 649	4 441	5 965	1 152
	Africa, south coast	32	19	151	143	109	256	380	2 316	2 816
	North America, northeast coast	–	178	–	13 244	11 435	15 870	14 471	13 369	11 200
	North America, southeast coast	–	–	35	–	–	2	–	6	31
	Other Atlantic	–	–	–	–	44	93	177	66	–
	Arabian Sea	2	20	–	11	–	–	123	200	32
	New Zealand	–	–	–	122	1	167	1 710	47	1 005
	Total	11 563	6 866	12 927	17 831	16 689	21 035	21 303	21 970	16 236
C: *Octopus* spp. (mostly *O. vulgaris*)	Africa, northwest coast	53 837	72 914	46 154	39 744	38 063	33 003	29 834	28 145	24 526
	Africa, south coast	–	–	–	–	–	–	–	–	9
	Arabian Sea	3	–	–	–	–	–	–	–	–
	Total	53 841	72 914	46 154	39 744	38 063	33 003	29 834	28 145	24 534

Table 3.3

Catch and CPUE of Nototodarus sloani sloani in the New Zealand waters
(Kawakami 1976a)

Year	Number of boats	November Catch	November CPUE	December Catch	December CPUE	January Catch	January CPUE	February Catch	February CPUE	March Catch	March CPUE	April Catch	April CPUE	May Catch	May CPUE	Total Catch	Total CPUE
1972-73	71	-	-	-	-	1 169	2.8	4 444	3.5	5 148	4.0	2 662	6.6	-	-	13 423	3.9
1973-74	156			194		5 774 5 968	2.4	4 535	1.5	2 603	0.9	952	0.8	7	0.3	14 761	1.5
1974-75	151	67		5 366 5 433	0.3	6 395	1.7	3 723	1.3	2 690	1.1	706	1.1	-	-	18 947	1.6
1975-76	128	135	2.1	3 807	1.5	6 663	2.0	3 974	1.2	4 215	1.8	754	1.5	-	-	19 598	1.6

Notes: 1. This table is made using the data calculated by Nihon Enyo Ika Gyogyo Kyodo Kumiai (Japan Far Seas Squid Jigging Co-operative Association)

2. The catches per boat per day were obtained by dividing the total catch by the total operating days of all boats operated

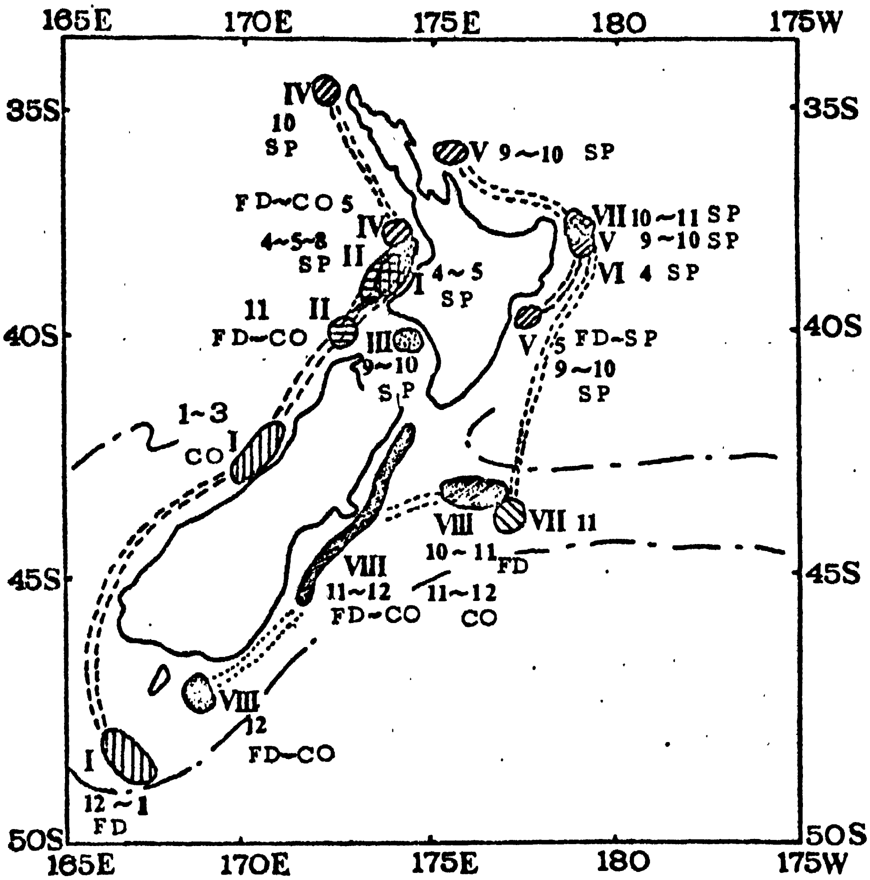


Figure 3.1 The local groups of Nototodarus sloani sloani in New Zealand waters (Kawakami 1976)

I: Western autumn subpopulation of squid attaining large size
II: Western autumn-winter subpopulation of squid attaining medium size
III: Central spring subpopulation of squid attaining large size
IV: Northern spring subpopulation of squid attaining small size
V: Northeastern spring subpopulation of squid attaining small size
VI: Northeastern autumn subpopulation of squid attaining small size
VII: Eastern spring subpopulation of squid attaining large size
VIII: Eastern summer-autumn subpopulation of squid attaining large size
1: January; 2: February; .....; 12: December
FD: Feeding season
CO: Copulating season
SP: Spawning season

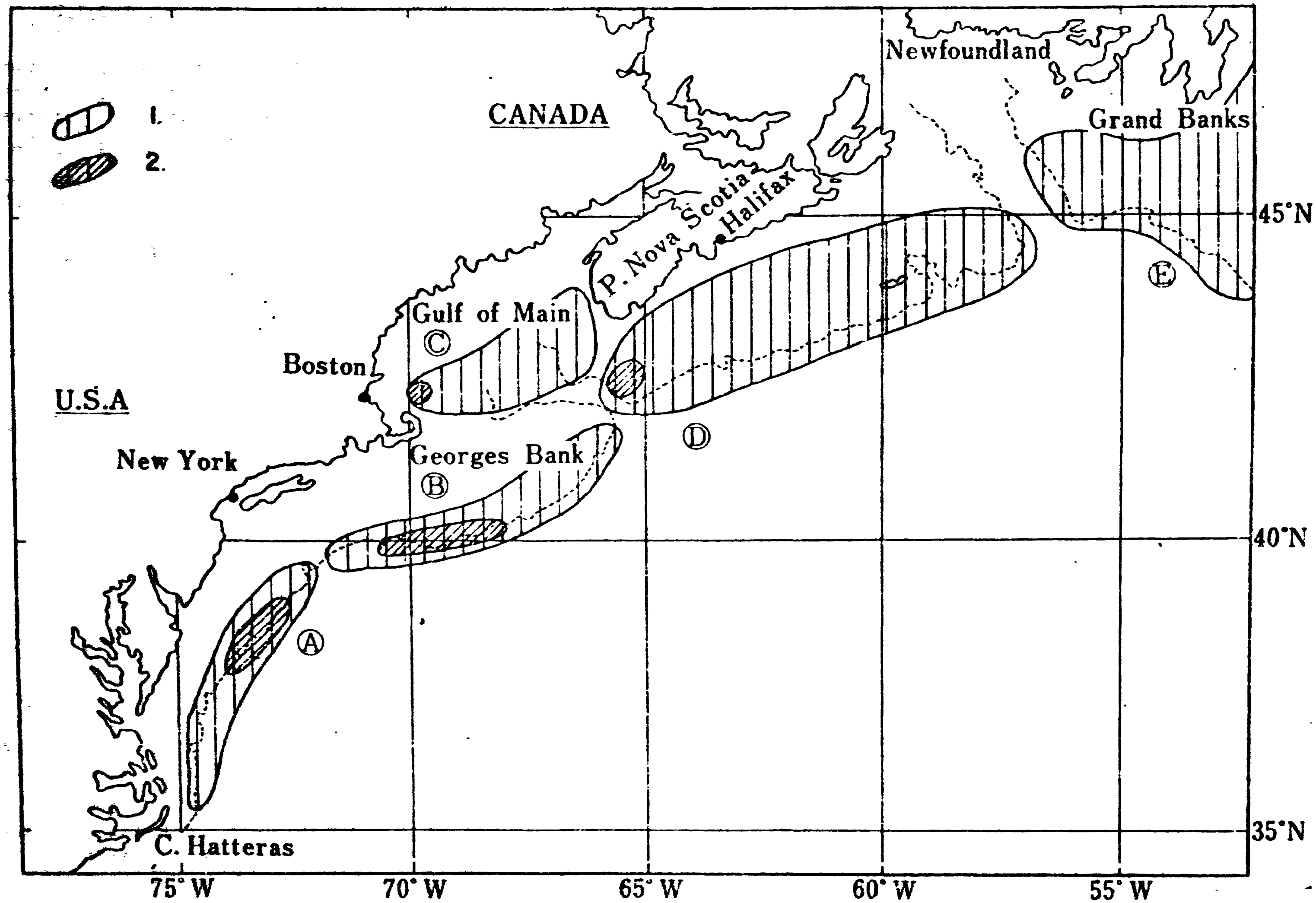


Figure 3.2 Surveyed area and catch by area (1: surveyed area, 2: main fishing grounds)

Table 3.4

The catch (C), number of fishing days (N) and CPUE for *Illex illecebrosus* (Ichikawa, Sato and Kawakami, pers.comm. 1977)

Year	South off New York			East off New York			Gulf of Maine			Off Prov. Nova Scotia			Off Newfoundland		
	C	N	CPUE	C	N	CPUE	C	N	CPUE	C	N	CPUE	C	N	CPUE
1973	1 020.0	10	120.0	74 485.0	55	1 354.3	7.5	1	7.5	997.5	21	47.5	240.0	17	14.1
1974	13 773.5	16	860.8	28 992.5	57	508.6	4 372.5	8	546.6	67 958.0	30	2 265.3	0.0	4	0.0
1975	119 482.5	44	2 715.5	153 652.5	68	2 259.6	-	-	-	30.0	6	5.0	-	-	-
1976	59 936.0	27	2 219.9	80 592.0	17	4 740.7	-	-	-	151 400.0	28	5 407.1	74 416.0	17	4 377.4

Year	Total		
	C	N	CPUE
1973	76 750.0	104	738.0
1974	115 096.5	115	1 000.8
1975	273 165.0	118	2 315.0
1976	366 392.0	96	3 816.6 a/

CPUE: Catch per day per boat
Vessels: One research boat every year. 1973: 469.69 GT, 1 000 PS; 1974 and 1975: 422.40 GT, 1 500 GT, 1 500 PS
Season: From June to October (5 months) every year
Gear: Automatic squid jigging machines. 1973: 26 machines; 1974: 29 machines; 1975: 32 machines per boat

a/ Includes offshore catch (C = 48.0, N = 7, CPUE = 6.9)

3.2.3 *Dosidicus gigas* (d'Orbigny) off California and Mexico

Although this species has been regarded as a huge latent resource for a long time, exploratory fishing by the Japanese research boat was the first attempt at catching this squid by jigs. The only data available are those of Sato (1976) (Table 3.5).

3.3 Demersal Species (Trawl Fisheries)

3.3.1 Cephalopod fisheries in the CECAF area

A number of countries trawl in the northern part of CECAF (Fisheries Commission for the Eastern Central Atlantic) area for long-finned squid (*Loligo forbesi*), cuttlefish (*Sepia officinalis*) and octopus (*Octopus vulgaris*). The third session of the CECAF Working Party on Resource Evaluation (FAO, 1976) was able to assemble total annual catches by species for the years 1965–1974, and corresponding series of catch-per-effort data based on Japanese and Spanish statistics. Particularly in the case of cuttlefish and octopus, the annual levels of catch per effort showed a close and consistent inverse relationship with calculated total effort. The relationship was not so clear in the case of squid, possibly because only the Japanese catch-per-effort data were usable and squid are an incidental catch in the Japanese fishery.

By fitting empirical curves to the available catch and effort data, the Working Party estimated that the maximum sustainable yields were 37 000 tons of squid, 46 000 tons of cuttlefish and 100 000 tons of octopus. It further concluded that while fishing effort for squid had in most years been below the level required to take the maximum sustainable catch, fishing effort for cuttlefish and octopus had exceeded that level. It therefore recommended that CECAF consider methods of reducing fishing effort on these species, noting that the current level of catches could be taken with substantially less effort to the overall economic benefit of the fisheries.

3.3.2 Cuttlefish resources in the Arabian Sea

The commercial fishery for cuttlefish by Japanese trawlers in the Arabian Sea began in 1967. In the early years up to around 1970 the Japanese cuttlefish fishery was carried out all over the coastal waters extending from Oman to Somalia. Subsequently the operations have concentrated on the waters off the coast of the People's Democratic Republic of the Yemen.

Four species of cuttlefishes are commonly found in the fishing grounds off the coast of the Yemen. They are three species of *Sepia*, namely *Sepia pharaonis* Ehrenberg, *Sepia savignyi* Blainville and *Sepia prashadi* Winckworth, and one *Sepiella* species, *Sepiella inermis* (Ferussac et d'Orbigny). It seems that *Sepia pharaonis* is most abundant among them and predominant in the catch of cuttlefishes by trawlers on these grounds.

Catch and effort data on the Japanese cuttlefish fishery are available since 1970, and recent catches by the Yemen and U.S.S.R. are estimated on the basis of information from the Japanese industry. The total catch of all countries increased from about 3 100 tons in the initial year to 7 300 tons in 1972, and declined thereafter to 5 300 tons in 1975.

The basic problem for the stock assessment of cuttlefishes is to determine the standardised CPUE (catch in tons per day) and effort (in days) from the original catch and effort data. The fishing efficiency of the Japanese large-sized trawlers that have joined in the cuttlefish fishery since 1973 is estimated to be 1.3 times that of the traditional medium-sized ones (Ikeda *et al.*, 1975). The ratio of fishing efficiencies enables us to express the Japanese effort and hence the CPUE in standard terms, corresponding to the traditional medium trawlers. From these, the total standardised effort is calculated annually by dividing the catch of all countries by the standardised CPUE.

Table 3.5

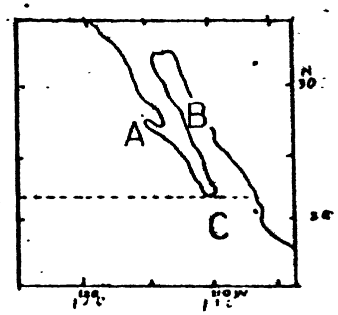
The catch of *Dosidicus gigas*, the number of operating days and the catch per day in the Californian waters by a Japanese squid jigging research vessel in 1971

Area	A			B			C			Total		
Month	Catch in kg	Days	CPUE in kg	Catch in kg	Days	CPUE in kg	Catch in kg	Days	CPUE in kg	Catch in kg	Days	CPUE in kg
October	23 272.5	27	861.9	255.0	1	255.0	-	-	-	23 527.5	28	840.3
November	727.5	6	121.3	60.0	5	12.0	1 297.5	7	185.4	2 085.0	18	115.8
December	30.0	3	10.0	427.5	3	142.5	202.5	5	40.5	660.0	11	60.0
Total	24 030.0	36	667.5	742.5	9	82.5	1 500.0	12	125.0	26 272.5	57	460.9

CPUE: Catch per day per boat

Vessel: 299.88 GT, 730 PS

Fishing gear: 17 automatic jigging machines and 10 hand jigging machines



Catch by countries, catch per standardised day of Japanese medium trawlers and resultant standardised fishing effort are shown in Table 3.6.

To assess the state of the stock, and to estimate, so far as is possible, the value of the maximum equilibrium yield from the stock, the CPUE was plotted as a function of the total effort (Figure 3.3). The biological information of life-span and age-composition is not well enough known to determine the span of time over which the fishing effort in a given year affects the CPUE. For the present analysis the CPUE has been related to the mean of the effort in the current year and in the previous year.

The regression line is shown in Figure 3.3 and is given by the equation

CPUE = 12.20 - 0.0057 (mean effort)

The correlation coefficient is -0.624. This is not statistically significant so that the true relation between effort and CPUE is not well established. One reason is the considerable year-to-year fluctuations, unconnected with fishing. However, the data do suggest that fishing is having an effect on the stock. Using the regression line of CPUE on effort, a relation between catch and effort can be estimated. This is also shown in Figure 3.3. It suggests that the maximum equilibrium yield might be about 6 500 tons taken with an effort of 1 100 standard days. If this is correct, the recent fishery has been operating at around the optimum level.

3.3.3 Loligo pealei in the ICNAF area

L. pealei is a benthic species of the northeastern coast of the United States (Cape Hatteras to Georges Bank). It winters on the continental slope, where it is caught by trawls, and migrates onto the continental shelf in spring and summer. Tibbetts (1975) has reviewed the general biology of the species and the development of the fishery, initiated by Japanese vessels in 1967. Mesnil (1976) has reported further details on the life cycle.

Sissenwine (1976) summarised stock size estimates to date, based on areal expansion of trawl catches by commercial vessels (Ikeda et al., 1975) and research vessels (Tibbetts, 1975). Kawahara (MS. 1977) and Mesnil (1977) have reported more recent work. Since L. pealei is distributed rather evenly on the bottom, these estimates based on trawl catches are relatively precise (compared to corresponding estimates for other species) and consistent with one another, although the size of the stock has, of course, shown considerable variation among years and seasons. Since 1970 the various estimates have ranged from about 20 000 to 120 000

Catches have averaged about 33 000 tons per year and there has been no indication of a declining trend in abundance; in fact, the stock appears to have been more abundant in recent years (since 1972) than it was earlier. As advised by its scientists (Au, 1975) ICNAF adopted the rule that the catch should not exceed 40 percent of the standing stock and so set a precautionary quota for 1977 at 44 000 tons. Mesnil (1977) argued that limiting the catch to this level was overcautious, even wasteful.

4. CONCLUSIONS THAT CAN BE DRAWN FROM THE PRESENT STUDY

4.1 General Considerations

Fishery biologists involved in cephalopod studies are agreed that the world cephalopod resources are not fully utilised, and that there are very great regional differences in the degree of exploitation. Two conditions are required before significant exploitation starts: a demand, and stocks that are accessible to current technology. World demand is very uneven being concentrated in Japan and southern Europe, though the demand in southeast Asia is steadily growing (Hotta, 1976).

Table 3.6

Catch, catch per day and fishing effort of cuttlefishes off the coast of P.D.R.Y.

Year	Catch in 1 000 tons				CPUE in tons per day b/	Fishing effort in days b/
	Japan	P.D.R.Y.	U.S.S.R.	Total		
1970	3.09			3.09	3.82	810
1971	4.66		0.50	5.16	5.88	878
1972	6.72		0.60	7.32	9.66	756
1973	4.75	1.00	0.60	6.35	5.47	1 161
1974	5.16	1.00 a/	0.70 a/	6.86	4.62	1 485
1975	3.61	1.44	0.20	5.25	6.38	823

a/ estimated

b/ standardised by two Japanese medium trawlers

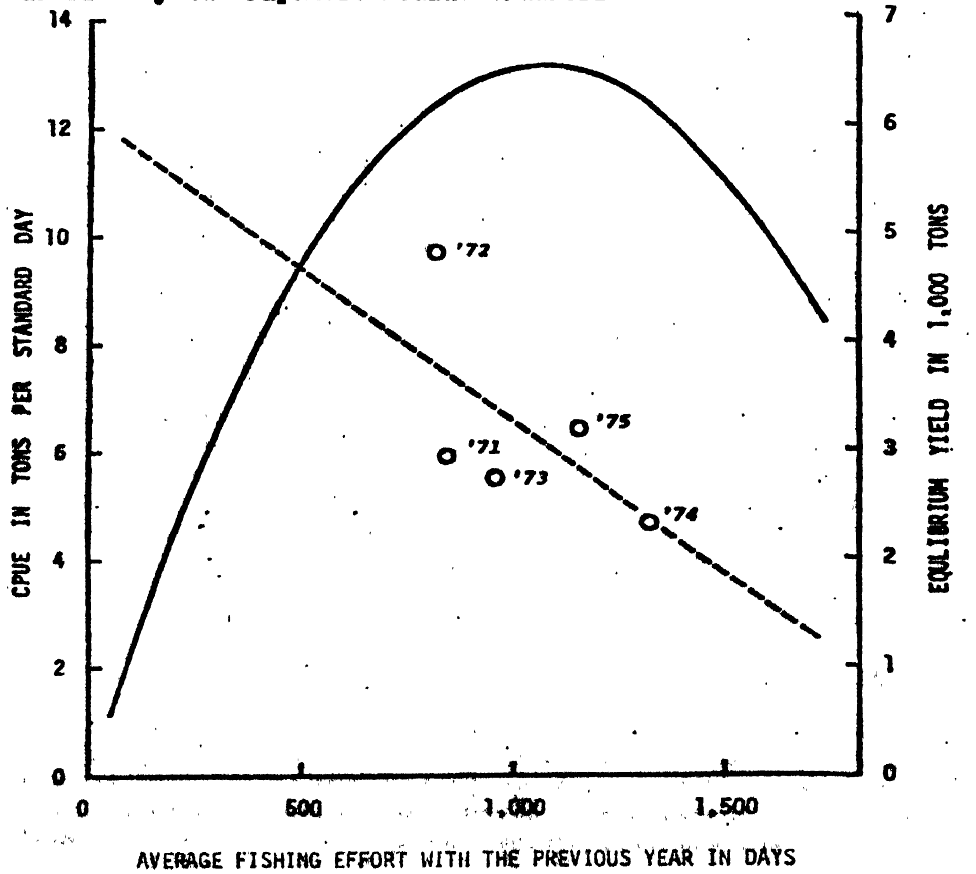


Figure 3.3 Relation between CPUE and average fishing effort in the previous year, and equilibrium yield curve for cuttlefishes on the fishing grounds off the coast of the People's Democratic Republic of Yemen

The traditional cephalopod fisheries have been based on neritic species by local using a variety of gears. Two developments have recently allowed the development of fisheries on a greater variety of stocks. First, long-distance trawling has allowed the exploitation of neritic stocks in regions where there is no local demand; second, improvements in the jigging fisheries have increased the exploitation of oceanic species, particularly at the fringes of their distribution where they come relatively close to shore. These factors have determined the pattern of development in the cephalopod fisheries of different regions of the world; they are set out in summary form in the left-hand part of Table 4.1.

Figure 4.1 shows the present geographical distribution of cephalopod fisheries, and Figure 4.2 shows the 1974 catch of major cephalopod groups in the various FAO statistical areas. The Northwest Pacific is the region with the greatest cephalopod catch of the world, followed by the western central Atlantic (off the coast of Africa). In the former area the Japanese nearshore fishery uses a great diversity of gears and methods. The latter area became exploited more recently by long-distant trawlers from Asia and southern Europe. These two areas, along with the Mediterranean Sea and a part of the Northeast Atlantic, are regarded as areas in which there are fully exploited cephalopod resources.

Of the individual fisheries in these regions, the jigging fishery of is one of the most important and may be the one having the greatest impact

The depletion of Todarodes pacificus catches in these years has been so pronounced that the maintenance of the stock at its recent level is now regarded as a serious problem since the fishing effort has remained at a high level. The increase of fishing effort on the autumn population in the Japan Sea has since 1972 failed to result in any increase in landings. The stock size of this population seems to have been overestimated at the initial stage of exploitation. At the time when the exploration of offshore fishing grounds was fully established, an increase of catches of smaller squid in the very early period of the fishing season and a decrease in the abundance of south-going shoals became apparent, and these phenomena have given an ill-effect on reproduction and recruitment of this population. The winter population taken in northern Japan also shows a pronounced depletion. One cause for this depletion may be variations in the natural biotic and abiotic environment, but some control of the fishing intensity upon the reduced populations is badly needed. In addition, systematic surveys of larval abundance and estimation of the stock size in the pre-exploitable phase must be undertaken to establish an accurate forecast of the availability of squid populations.

4.2 Shift of Species

In addition to changes in the stocks of individual species typical of the effects of heavy fishing, other changes have occurred in some areas of intense exploitation. In the Northwest Pacific, as the catches of Todarodes pacificus decreased, the commercial catches of Ommastrephes bartrami, which had only been little utilised, increased.

The changes in catches of these species, their general distribution, and possible interactions are discussed in more detail in section 2.5.3. Here it is sufficient to note that while there have been changes in fishermen's preferences, and improvements in the tech-niques of processing Ommastrephes, there have been real changes in the distribution of Ommastrephes, possibly caused by the decrease in Todarodes.

A change of species composition has also been observed in the trawl catches in the CECAF area and in the Gulf of Thailand. The proportion of cephalopods among trawl catch has tended to increase following an increase in general trawling activity. Changes in the commercial catches may be partly artificial (due to changes in preferred trawling ground, or market value, etc.), but in the Gulf of Thailand the catches in research surveys have also changed, and this must reflect a real change in species composition.

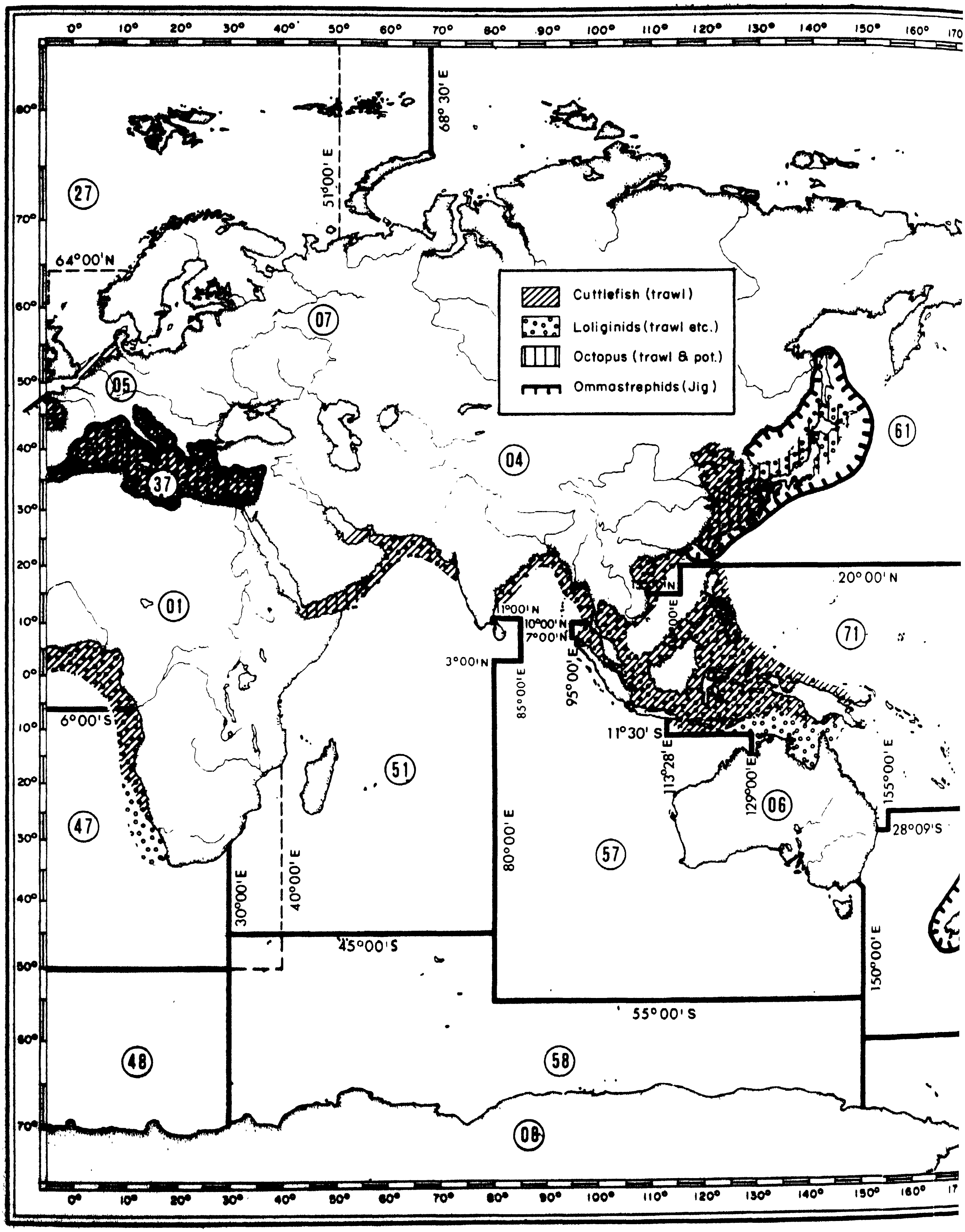
Table 4.1

Condition of exploitation and latent stock of the cephalopod resources in the world

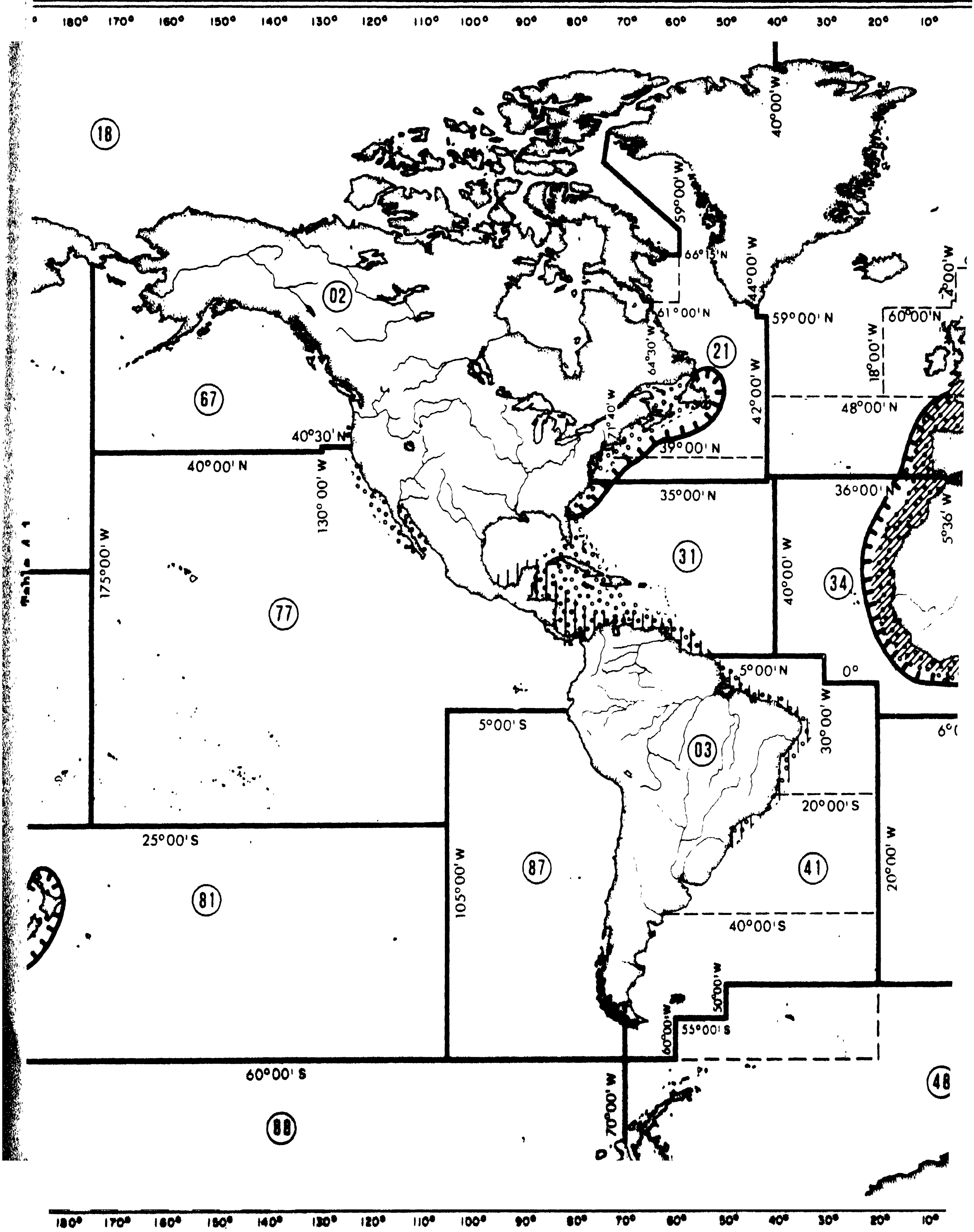
Area	Catch[a] (x 10^3 tons)	Local demand	Existing fishery		Major species	Possibility of increase	Possible promising species (Latent species or stock)
			Local	Long-distant			
ATLANTIC							
Northwest	50	Low	+	++	*Loligo pealei*, *Illex illecebrosus*[b]	+	*Illex illecebrosus*[b]
Northeast	250	Low	+	+	*Sepia officinalis*, *Loligo vulgaris*	++	*Todarodes sagittatus*[b]
West coast	4	Low-moderate	+	+	*Loligo pealei*	+	*Loligo plei*, *Octopus maya*
East coast	200	Very low	+	++	*Sepia officinalis*, *Loligo forbesi*	+	
Southwest	5	Low-moderate	+	−	*Loligo* ?	+	*Illex argentinus*[b]
Southeast	2	Very low	−	+		++	*Sepia* spp.
MEDITERRANEAN	40	High	++	−	*Sepia officinalis*, *Loligo vulgaris*, *Octopus vulgaris*	−	
INDIAN							
West	7	Very low	−	+	*Sepia pharaonis*	++	*Sepia pharaonis*, *Symplectoteuthis ovalaniensis*[b]
East	<1	Very low	−	−		++	*Sepia* spp., *Nototodarus sloani*[b]
PACIFIC							
Northwest	240	Extremely high	+++	−	*Todarodes pacificus*[b], *Octopus vulgaris*	+	*Ommastrephes bartrami*[b]
Northeast	<1	Very low	−	−		+	Gonatidae[b], *Paroctopus apollyon*
West coast	120	Moderate	++	−	*Sepia* spp., *Loligo* spp.	++	*Symplectoteuthis ovalaniensis*, *Loligo* spp.
East coast	10	Low	+	−	*Loligo opalescens*	+	*Dosidicus gigas*[b]
Southwest	20	Very low	−	++	*Nototodarus sloani*[b]	++	*Nototodarus sloani*[b]
Southeast	<1	Very low	−	−		++	*Dosidicus gigas*[b]
SOUTHERN OCEAN	−	Nil	−	−		++	*Todarodes filippovae*[b], *Moroteuthis ingens*[b]

a/ FAO (1974), b/ Oceanic species

Figure 4.1 Present geographic



al distribution of major cephalopod fisheries of all countries. (The circled numbers denote FAO s



stical areas)

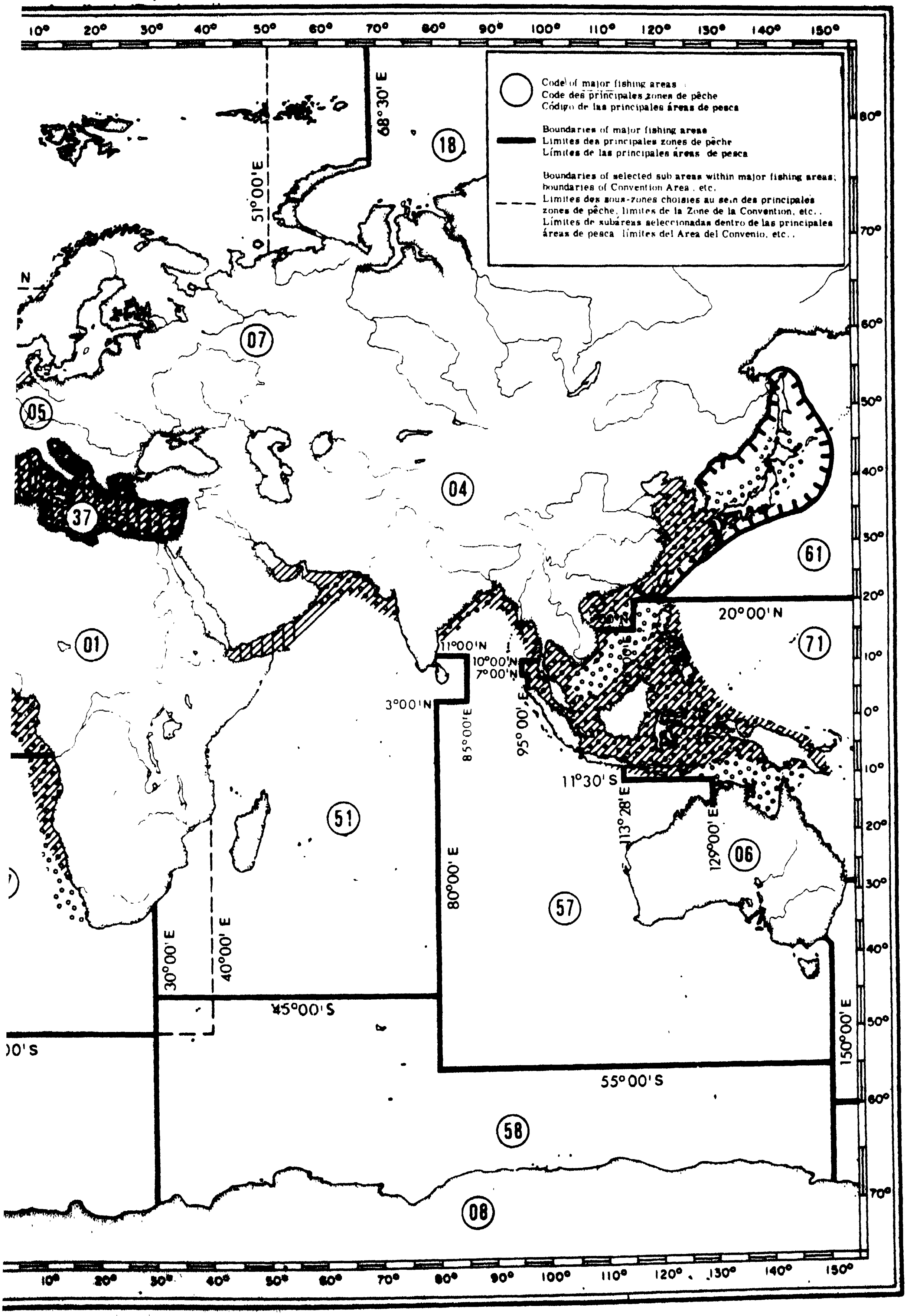
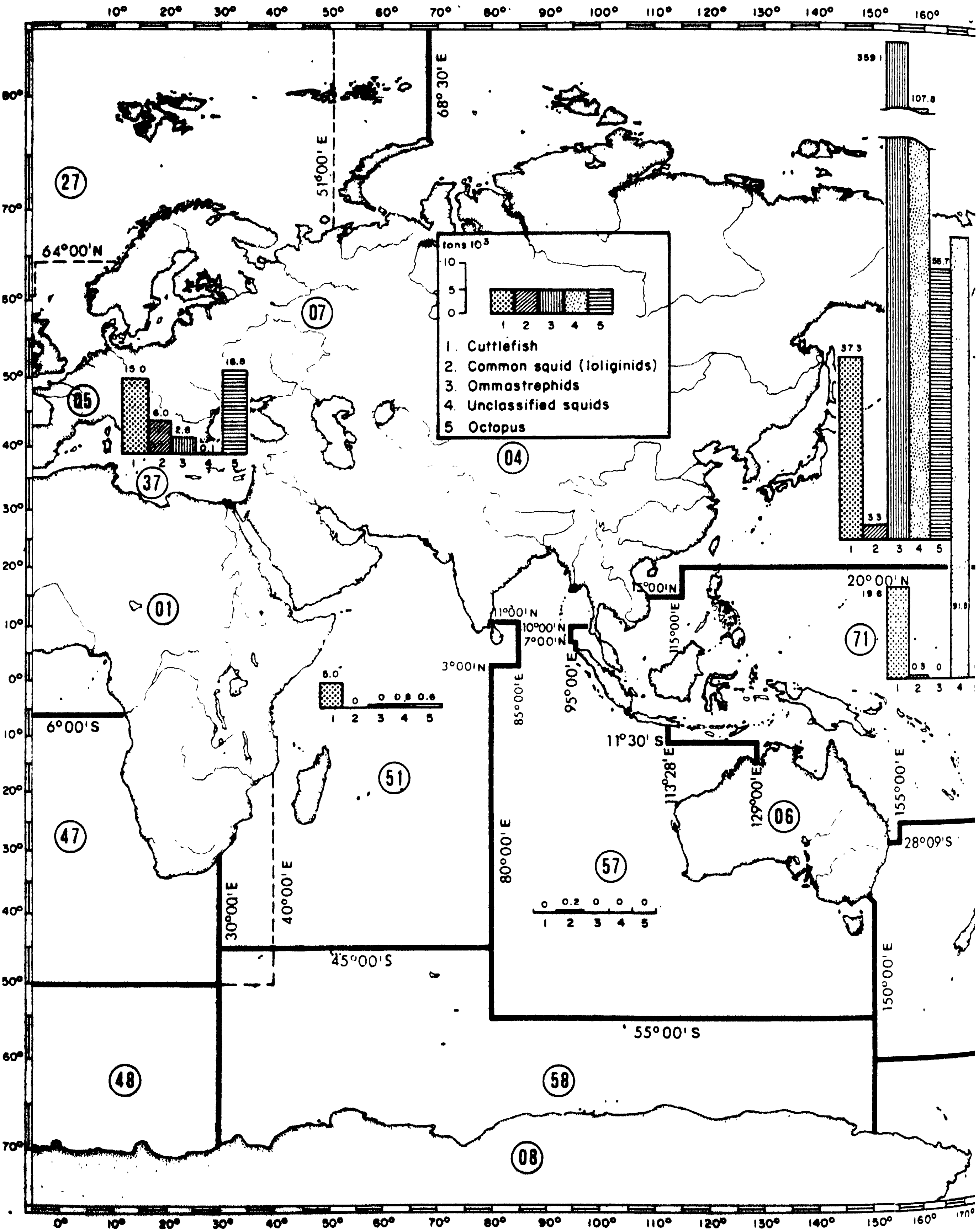
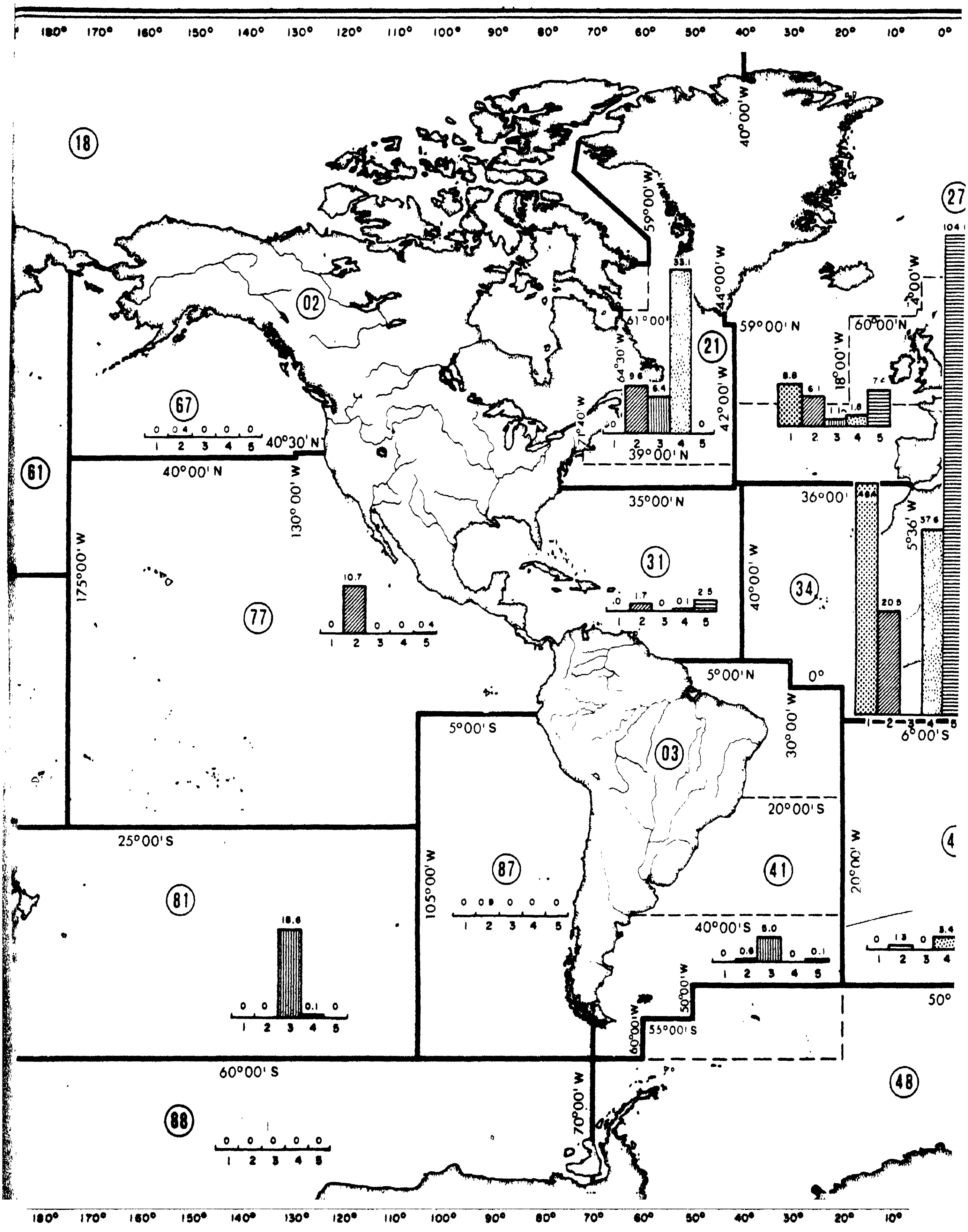


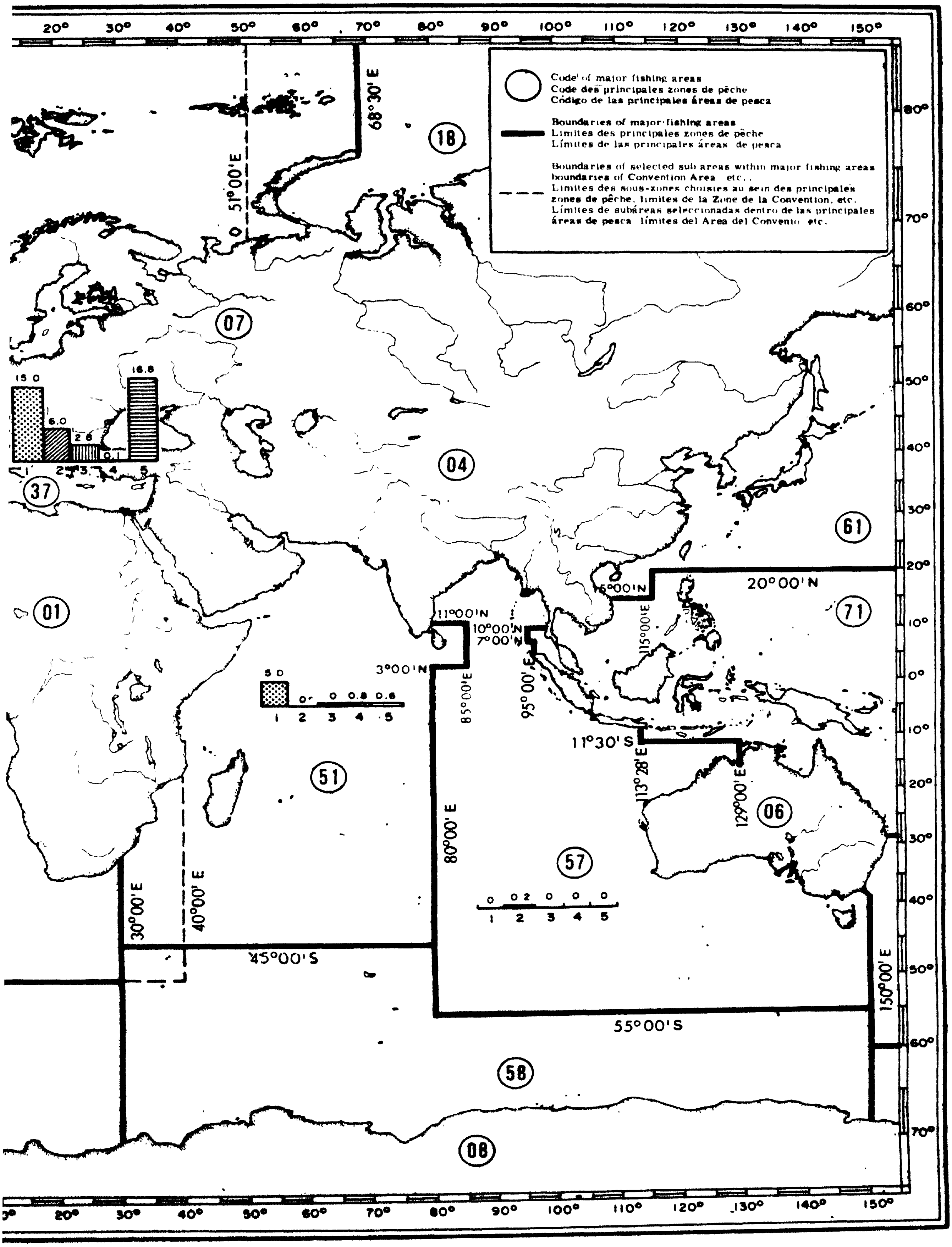
Figure 4.2 Total cephalopod catches b



y all countries in 1974 within the various FAO statistical areas. (The circled numbers are indices



e statistical areas)



These experiences in the more heavily fished areas provide some guidance to the possibilities for further expansion. These are indicated in summary form in the right hand part of of Table 4.1.

Some increase in catches should be possible from neritic species. Octopus are fully exploited around Japan, and probably in most of the Mediterranean. Elsewhere prospects are more promising. For example, in the Northeast Pacific there may be a large stock of Paroctopus dofleini, which is highly appreciated in Japan and doubtless could be marketed in much larger quantities.

Similarly, cuttlefish catches may be increased away from the present main grounds. Sepia occurs widely in the Indian Ocean from the Red Sea eastward, but is only exploited locally. A variety of species, including the large S. apama occur around Australia. Among neritic squids of the family Loliginidae, untouched stocks may occur in the waters of south-east Asia and northern Australia (e.g., Loligo chinensis, L. edulis, etc.) and also in the Caribbean and adjacent areas (L. plei, L. surinamensis, etc.). As these are all neritic animals living on the shelf area, they may be suitable for harvesting by local small-scale fishing rather than by large ocean-going vessels.

The greatest possibilities for large increases in catch lie with the oceanic squids of the family Ommastrephidae. Taking account of the distributions of the species already utilised (Todarodes pacificus, Nototodarus sloani, Illex illecebrosus) and of the little utilised species, it can be said that these important ommastrephids inhabit belts between latitude 30° and 50° both in the northern and southern hemisphere. Within these belts, they breed in the subtropical to warm temperate zones as propagation area and feed in the warm- to cool-temperate

Little systematic biological and ecological studies have been made of the unexploited species. However, if their ecology, including aggregation and migration pattern, sexual maturity and population structure are analogous to T. pacificus, studies of the latter species can be used to establish a guideline to population analysis. In fact, a considerable success in development of a fishery on Nototodarus sloani sloani was achieved in this way. The fishery for this species is now well established with catches of 20 000 to 30 000 tons by some 150 jigging boats. In this fishing area, more fishing effort could yield more catch. Another resource, Illex illecebrosus in the waters off New York to Newfoundland, has investigated since 1973 using the same principle. The early survey was unsuccessful, but a single boat could catch 400 tons in the most recent exploratory fishing. Analogy and application of knowledge on T. pacificus seem to fit well to this species. A third species, Dosidicus gigas is believed to form a huge stock in the eastern tropical Pacific. It has been investigated by a single research boat. The survey is suspended at present, but could be continued in the future. The current fishery on Ommastrephes bartrami may provide clues to the future development of fishing on this species.

Another oceanic species, Symplectoteuthis oualaniensis, which has a huge stock in the vast Indo-Pacific region, is now subjected to commercial fishery in the islands of Taiwan and Okinawa. It is widely distributed in warm waters, but it is reported that this squid is difficult to concentrate under fishing lamps. This may be because the subtropical environment in the fishing ground is so uniform that there are no strong oceanographic discontinuities such as fronts which help to aggregate the shoals.

A subarctic species, Berryteuthis magister and some other gonatids, is known to be very ——dant in the subarctic region. Some Japanese trawlers occasionally catch this squid in a large quantity, but the flesh of this squid has a high water content and processing presents technical problems. This situation may also occur with Moroteuthis ingens, an abundant squid in the subantarctic

Other promising ommastrephid stocks include Illex argentinus in the Southwest Atlantic and Todarodes filippovae in the subantarctic areas. In the Atlantic Illex coindetii and Todarodes sagittatus (including subspecies antillanum) have been caught by trawling in small quantities, and may possibly be exploited on a large scale by jigging.

5. SUGGESTIONS FOR FUTURE WORK

Taken as a whole cephalopod resources are underutilised. The exceptions include the stock of Todarodes pacificus around Japan, and some demersal stocks off the coast of North-west Africa. The most important biological work is therefore to identify and explore the underutilised resources. In addition technical and economic work is needed to improve methods of catching and processing, particularly to develop the market for and use of squid in parts of the world where few cephalopods are presently consumed. These latter questions are not discussed further here.

For exploring latent, unutilised stocks, the combination of trawlers and jigging boats appears to be most desirable. Exploratory trawl fishing has played an important role in locating resources which now support prosperous jigging fisheries.

Quantitative assessment of cephalopods is difficult. The few assessments so far made are largely based on the analysis of catch and effort data of commercial fisheries. These cannot be made until large-scale fishing has been in progress for at least a few years. To improve these assessments, and to enable quantitative estimates to be made earlier, catch/effort data need to be supplemented by other information, including:

(a) accurate identification of species;

(b) population structure within species, particularly those covering large areas;

(c) information on the life-cycle, including migration patterns;

(d) direct estimates of standing stock.

The last of these may require the development of new or improved techniques for surveying cephalopods. It is likely that different methods, or at least different emphasis, will be given when assessing different groups of cephalopods, e.g., large oceanic species as compared with small benthic species.

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